July, 187

1. See opposite.

2. Morris, Ellwood. ... Review of the Practical Views, etc.

3. Roberts, W. M. Improvement of the Ohio. Explanatory remarks on the "Review" of Ellwood Morris.

PRACTICAL VIEWS

ON THE

PROPOSED IMPROVEMENT

OF THE

OHIO RIVER,

BY

W. MILNOR ROBERTS, CIVIL ENGINEER.

PHILADELPHIA:
FROM THE JOURNAL OF THE FRANKLIN INSTITUTE.
1857.

DEDICATION.

HON. JEREMIAH S. BLACK,

ATTORNEY GENERAL OF THE UNITED STATES.

Respected Sir:—

Permit me to dedicate to you the following pamphlet on the subject of the Improvement of the Ohio River. Dedications, at the present day, are not so much in vogue as in the olden times; yet there is no very good reason why they should be prohibited, or be suffered to fall into entire disuse. In this particular instance, your attention having been already turned to the consideration of the very important question, which forms the theme of this paper, you will be less surprised at my desire to benefit by your judgment.

These views are respectfully offered, through you, to the practical, thinking men of our country. If they shall be found to stand the test of one of the best and most practical minds which has ever graced the annals of Pennsylvania jurisprudence, or adorned the cabinet of the United States, it will not only be personally gratifying to their author, but may do much good by inducing others to give the subject a more patient investigation.

Your home is in Western Pennsylvania, not far from the head of the great Ohio River; that river which, notwithstanding its present precarious navigation, arising from great irregularities in the flow of its waters, bears upon its bosom, annually, a more extensive and valuable commerce than the united traffic on all the great East and West railroads in the Union.

Whether the conclusions of the writer will meet with your approbation, and receive the sanction of the practical judgment of the country, the future will determine. However this may be, Sir, be assured, that although it may be impossible for a man to be impartial in the treatment of conflicting plans, when one of them has the approval of his experience, and the others are in a manner experimental, I have at least endeavored to deal fairly with all of them.

Regarding this great work—the permanent improvement of the Ohio River, as a national necessity,—I feel no hesitation in addressing a national man, in whose straight-forward opinion, the public will justly repose much confidence.

From a comparatively limited practical sphere, I thus appeal to that larger and more national circle, which includes many of the soundest judgments in the land; trusting that another session of Congress will not terminate without final and effectual action, such as will *secure* the speedy, radical improvement of the Ohio River on the best plan, whatever that may be.

With the highest esteem and respect, allow me to subscribe myself,

Your friend,

W. MILNOR ROBERTS.

Keokuk, Iowa, 1857.

PRACTICAL VIEWS

ON THE

PROPOSED IMPROVEMENT OF THE OHIO RIVER.

BY W. MILNOR ROBERTS, C. E.

From the Journal of the Franklin Institute.

THE OHIO RIVER constitutes a part of the most extensive inland navigation known to the world; and if anything whatever in the interior can be so regarded, it is eminently national in its character. Eight States—New York, Pennsylvania, Virginia, Maryland, Ohio, Kentucky, Indiana, and Illinois, are watered by the Ohio and its tributaries; and eight more—Wisconsin, Iowa, Missouri, Tennessee, Arkansas, Alabama, Mississippi, and Lousianna, are directly connected in navigation interests, through the Missouri and Mississippi Rivers. To these may be added, the Territories of Minnesota, Nebraska and Kansas. Texas, also, on the Gulf of Mexico, is in very direct water communication with the navigation of the Ohio River. These States and Territories comprise within their limits, even now, more than half the population of the Union; and since the introduction of the railroad system, working in harmony with these grand internal water communications, the commercial interests of all the States have become so interwoven that all are in reality interested in maintaining the navigation of this river.

The value of the commerce passing annually along the thousand miles of river between its head at Pittsburgh, and its mouth at Cairo, is enormous—not less than three hundred millions. And the business would annually increase much more rapidly but for the frequent and long continued interruptions caused by want of water in the channels. Hence, the preservation and improvement of this stream as an economical avenue for the interchange of a national commerce, has assumed a national importance.

The destruction or serious injury of a channel so advantageously placed, and forming a vital link of an almost boundless system, would therefore injuriously affect the commercial, manufacturing, and agricultural interests of the country. Such, indeed, has been the case to the extent of millions of dollars in more than one season, and especially in 1856.

Steam has given to our rivers an importance as commercial arteries which can scarcely be overrated, and the steamboat interest on our western waters now includes an aggregate capital of at least one hundred millions; over twenty millions of which are invested in steamboats alone. The interior steamboat interest is second only in amount to the railroad

capital; the two combined, taking the entire Union, probably amount to one thousand millions of dollars.

Regarding our rivers and railroads, with their steamers, and locomotives, and cars, as the machinery for the mere *movement* of the trade and travel of the States, what must be the grand aggregate value of the things conveyed? Before the introduction of the steamboat, the trade on the Ohio River, and on all of the western waters, was quite small, and confined chiefly to descending craft which floated with the current. Had the same primitive mode of conducting business continued to this day, the increasing irregularities in the navigation would have attracted little attention, because of the comparatively trifling interests concerned. But the country, through the instrumentality of steam, having become familiar with the real value of a great river navigation, and with its intimate and friendly relationship with the railroad system, now looks with anxious concern upon the melancholy fact which cannot be denied, that the river, instead of becoming better, is gradually becoming less and less reliable as a navigation. The cause of this failure appears to be almost by common consent ascribed to the gradual clearing away of the timber from the head waters and along the main streams. It seems to operate in two ways: by lessening the annual downfall of rains and snows, and by augmenting the annual evaporation.

For months consecutively, and occasionally through almost an entire business season, no dependence can be placed upon the river as a channel of shipping, particularly by those living at a considerable distance therefrom, as there is a general apprehension that by the time goods may reach a given point, the water may have receded. This causes millions of dollars worth of property to lie idle for long periods as dead capital; restricts the manufacturing capabilities of the manufacturing cities, limits the agricultural productions, and of course decreases the commercial prosperity of the country. The evil has become so notorious—the public feeling so aroused to the necessity and expediency of attempting some radical remedy, that little doubt can be entertained that Congress during its ensuing session, will at least provide for the necessary preliminary surveys and investigations, or in such manner as will speedily determine the question as to the best plan for permanently improving the river.

Having conceded that Congress will probably pass a law authorizing the examination of the whole subject, the inquiry naturally arises, "why then discuss it in advance?" In answer, it may be said, that although there are some features the merits of which can only be finally settled from the results of actual surveys, there are others, important and interesting, which the engineers and practical men generally of this country, may investigate beforehand; the elaboration and determination of which are not dependent on future surveys: that there are elements enough already within reach, worthy of the attention and examination of the ablest minds of the land.

The question is not merely one of dollars and cents that may be involved in the adoption and completion of a particular plan; it is of the first consequence that that plan shall be one with which the sober good sense of the country will rest satisfied, and which, in the end, will be productive of the greatest benefit.

The engineering features are of sufficient magnitude to entitle them to the candid and thoughtful consideration of the entire profession; and a fair discussion of them should be encouraged and aided by our civil engineers. Several members of the profession have already taken part in it, and in their different papers and publications may be found many interesting views.

Much desultory writing, and various crude suggestions have been thrown off for a long period of years; and for several years, between 1837 and 1840, the government was actually engaged in improving the river by means of loose stone wing dams, but without much effect. Locks and dams were suggested at an early day by Edward F. Gay, Esq., Civ. Eng., and others; and in 1839, after some experience on the Slackwater Improvement of the Monongahela River, the writer ventured to entertain and express the opinion that at some future period the Ohio River might be thus improved.

In 1849, Charles Ellet, Jr., Esq., Civ. Eng., wrote a paper on the subject of the "Physical Geography of the Mississippi Valley," published by the Smithsonian Institution, in which he promulgated and recommended his plan for the improvement of the Ohio and other western rivers, by means of *Artificial Reservoirs*, to be constructed on the navigable branches, or on the smaller tributaries. The water thus stored to be drawn out in dry seasons, to keep up the regular flow of the rivers. The same general ideas were reiterated, in a larger work "Upon the Mississippi Overflows," published by Lippincott, Grambo & Co., of Philadelphia, in 1853. In March, 1855, Josiah Copley, Esq., an intelligent gentleman of Pittsburgh, who had paid considerable attention to the subject of the improvement of the Ohio, prepared an article which was published by direction of the Board of Trade; and January 1st, 1856, another, both appearing in pamphlet form, under the auspices of the same Board. Mr. Copley has exerted himself not only in writing, but in various ways to point out and enforce the great necessity and importance of a radical improvement of the river.

In 1855, Herman Haupt, Esq., Civ. Eng., published a work in pamphlet form, entitled "a Consideration of the Plans for the Improvement of the Ohio River," in which, after reviewing the plan of "Locks and Dams," and the "Reservoir Plan," he proposed a third plan, to consist of a succession of open dams of 6 to 10 feet height, without locks; the pools to be connected by an open channel 200 feet wide; the channel to be formed by means of mounds or embankments extending lengthwise from the end of the dam far enough up each pool to equalize the flow. In fact, it would make a navigable canal 200 feet wide, with an average descent between Pittsburgh and Cairo of about 6 inches per mile.

In the Spring of 1856, Mr. Ellet condensed and arranged his views into a more popular shape, and published them in the *Cincinnati Gazette*. Soon after, at the request of a friend, an answer was prepared by the writer, which was published by the Board of Trade of Pittsburgh. This answer was not designed to be regarded as the argument on behalf of locks and dams; its main object being to correct what appeared to be

erroneous in the published papers of Mr. Ellet. It was republished in January of this year, in the *American Railway Times*, Boston.

In January, 1857, Ellwood Morris, Esq., Civ. Eng., commenced the publication of a paper "On the Improvement of the Ohio River," in the *Journal of the Franklin Institute*, which was continued in February, and concluded in the March number. It has since been published in a separate pamphlet.

It is certainly true, that the writings of these three gentlemen, Messrs. Ellet, Haupt, and Morris, as literary productions, are highly creditable to the profession.

Previous to the publication of any of these papers, in 1838 and 1839, Major (then Captain) Sanders, of the Topographical Engineers, was engaged as Government Superintendent; first, in surveying the Ohio River, and then in planning and carrying into execution certain improvements (already alluded to,) partially by means of wing dams, and partially by cleaning out the channels. Even after the suspension of these operations, Major Sanders continued the advocate of that method of improving the navigation; although it is proper to state, in this connexion, that he promised only a two and a half feet stage in low water, without the aid of artificial reservoirs. Considerable money was expended, some good was accomplished, but the appropriations were discontinued, and the work ceased. A further reference to this plan will perhaps be made, incidentally, in the course of this paper.

Long anterior to this period, from 1824 to 1826, a private corporation styled the "Louisville and Portland Canal Company," had constructed a steamboat canal and locks around the Louisville Falls, under the direction of Canvass White, Esq.,* Civ. Eng. The locks were made of sufficient size to accommodate the steamers of that day; but the great increase in the dimensions of steamers afterwards led to much inconvenience. Many being too large to pass through the locks, could only "run the falls" during high water. Government became a purchaser of the stock of this company, and now controls the works. Extensive repairs were made to these works in 1856, at the expense of the general government, under the direction and superintendence of Edward Watts, Esq., Civ. Eng., who, at the instance of the War Department, has furnished plans and recommended an appropriation for their permanent enlargement on a magnificent scale. This is the most difficult and expensive point on the whole river.

From 1837 to 1840, the writer was engaged as Engineer of the Monongahela Navigation Company, in surveying that river, and planning and erecting the locks and dams forming the slackwater between Pittsburgh and Brownsville. He afterwards made a survey for the Ship Canal, at the Sault St. Marie, and aided for a number of years in urging that great work upon the public attention. But it should not be inferred that it is his design to make this paper a mere advocacy of any one plan for improving the Ohio River. On the contrary, it shall be his aim carefully to examine, and fairly present all the plans, for the further consideration of the public; holding this paper like those papers he shall consider, subject to criticism from any interested party.

* Some time since deceased.

It is proposed to consider the several plans in the following order:

1st. The *Reservoir Plan* as proposed by Mr. Ellet; chiefly as modified in detail by Mr. Morris.

2d. The *Low Dam and Chute Plan* without locks, as proposed by Mr. Haupt, but chiefly with some modifications suggested by the writer.

3d. The "System of Locks and Dams," with sluice-ways or chutes for descending craft.

I. The Plan of Artificial Reservoirs.

It is stated, that the area of country drained by the Ohio River, its confluents and tributaries, above the City of Wheeling, is 24,337 square miles. From a careful examination of good maps showing the sources of the streams, the writer believes that this is sufficiently accurate for all the purposes of this discussion.

Estimating the *available* average annual downfall of water in the region under consideration at 12 inches,* the whole number of cubic feet would be 678,476,620,800. So that if the whole were stored in reservoirs, it would afford a daily flow of 1,842,401,700 cubic feet; which according to the calculations made by Mr. Ellet, of the quantity passing at Wheeling at different stages of the river, would give a constant depth of *eight* feet. It is proper to mention, however, that during one year, as shown by the record kept (in 1845), the actual flow, according to Mr. Ellet's calculations, would have furnished a constant depth of but 7 feet over the bar at Wheeling. This proves from the calculations, that there has been a year when the available downfall was less than 12 inches. It was in fact but 9·83 inches, according to the calculations of Mr. Ellet and Mr. Morris.

But the record of the height of water at Wheeling, kept through a period of years, as elaborated by Mr. Ellet, having shown that more than enough water passed down, *even in the driest year*, if it had been equalized throughout the season, to have afforded a constant depth of more than six feet; and any reasonable calculation based on the extent of country drained, showing a like result, it leaves no room for controversy in regard to the first important proposition; and it must be granted that enough water *falls* every year, if it could be equalized, to give six feet depth constantly over the bar at Wheeling.

The object of the advocates of the artificial reservoir plan, being to secure a constant depth of six feet at Wheeling, we may next consider whether the data obtained from the daily record of the height of the river, taken in connexion with the measurements of the rate of flow, and the calculations based thereon, are sufficient to show, without further examination, how much water must necessarily be stored in reservoirs to accomplish this result through the driest year recorded. This second point has been but imperfectly investigated, and yet without further surveys, some additional light can be thrown upon it.

The driest season, 1845, would have yielded an average depth of but *seven* feet at Wheeling, from an available downfall of less than 10 ins.;

* The important practical question—how much water from drainage may annually be *relied upon* to be stored in artificial reservoirs draining given areas? will be considered in another place. (See Appendix A.)

and yet Mr. Morris assumes in his calculations, 18 inches as the reliable depth from the drainage of 3600 square miles; and also, that the drainage of this area is to be stopped and held by six dams, not exceeding 100 feet in height. Now, as works of this sort must be planned for extreme cases in order to be constantly useful, would it not be the part of prudence to take the dry seasons as the gauge? Similar seasons in future may be more frequent than they have been in the past. Founding our calculations on such a dry season, we ought not to assume much more than half of the depth allowed by Mr. Morris as available from the drainage; though other engineers as well as the writer, in reference to this very region, have heretofore estimated a depth of 12 inches, or two-thirds of Mr. Morris's quantity. Mr. Ellet says, "The discharge is therefore about 40 per cent. of the total fall, showing that 60 per cent. of all the rain and snow that come to the earth in this latitude is carried back to the clouds in vapor and never reaches the ocean," and that "the *average* annual fall of rain at the head of the Ohio is 36 inches." Now this necessarily implies, that in some years it must be *less* than 36 inches. The experience of the writer, in connexion with a reservoir on one of the tributaries of the Ohio above Wheeling, led to the conclusion that it is not safe in this latitude to count on saving or utilizing more than 33⅓ per cent. of the annual downfall of rain and snow. A further investigation of this very point made some years ago by the writer at the instance of Major Walter Gwynn, Civ. Eng. of Virginia, confirmed this opinion. This being settled, it would, according to the other calculations of Mr. Morris, require *nine* instead of *six* large reservoirs of capacity sufficient to contain the drainage of 600 square miles each, and 5400 square miles in the aggregate. And of course, if his estimate of $12,000,000 for six reservoirs be correct, it will be equally correct to assume $18,000,000 for nine.

But the elements which belong to the moderately sized reservoirs, hitherto constructed in this and other countries, for the purpose of supplying canals or water-works, will not be found as component parts of the *immense artificial lakes* introduced into this question, as means for maintaining a steady flow in large navigable rivers. Where a reservoir is to be constructed large enough to hold the entire drainage of 600 sq. miles, (even allowing but 12 inches instead of 18 to be available,) there is little opportunity of choosing sites "near or upon elevated grounds, with moderately steep water-sheds of ordinarily impervious material;" because if you take sites near or upon such elevated grounds, you cannot command the drainage of enough territory to meet the other requirement—600 square miles. Again, Mr. Morris perhaps, without sufficient scrutiny of the calculations of Mr. Ellet respecting the quantity of water that a given height of dam will hold in check, has largely over-estimated the actual capacity of any such reservoirs. He proposes dams of 100 feet height, and assumes that they will afford over the whole superficial area overflowed, an average depth of half the greatest depth at the dam; whereas, it will be found, that this average depth will not be more than one-third to four-tenths of the greatest depth at the dam. It is practicable to build dams 100 feet high on the tributaries; but is it practicable to unite with them the requirements of 600 square miles of drainage, and the capacity of the reservoirs to contain the drainage, for nine such struc-

tures, or for six, or what number? In the case of a *small* reservoir, such as might yield a supply for the Ohio River for half a day, it is barely possible that a site could be secured where the average depth might be *nearly* half the greatest depth at the dam;* but for the *great reservoirs* now under consideration, the average of half the greatest depth can only apply to that portion of the reservoir which is directly above the natural *bed of the stream* itself. Whatever space is occupied by the bottom lands, and side hill slopes of the valley, must go to reduce the average depth. The surveys, if made, will probably show that *one-third* of the greatest depth is a liberal average to allow. This would reduce the *capacity* of the assumed reservoirs one-sixth.

Take an ordinary case of a stream 300 feet wide, falling 4 feet per mile, with bottom land on one side 500 feet wide, 25 feet above the stream, and side hill slopes of 4 feet base to 1 foot rise. Throw across a dam 100 feet high; the average depth even *at* the dam is but 65·8 feet, and half way up the pool, but 31·1 feet. Take another case similar to the above without any bottom land: the average depth at the dam will be 63·6 feet, and half way up the pool 35·7 feet. And where there are bottom lands of even moderate height, the upper miles of the reservoir would be confined within the narrow limits of the natural stream. In a vast majority of all the reservoirs which could be formed either on the main streams or on the tributaries under consideration, the actual shape of the whole prism of water will be found to approach the form of a *cone* more closely than that of the *wedge*. Hence it will not answer to assume one-half the greatest depth at the dam as the average depth of reservoirs.

Starting upon the data assumed by Mr. Morris, that each reservoir is to hold the drainage of 40 by 15 miles, or any other shape containing 600 square miles, we at once determine one point: that the dam must not be erected above the point commanding that drainage.

A second point may be determined without additional surveys: that in order to secure one of the important elements of these proposed reservoirs, namely, not over 4 feet per mile fall in the stream, it will be necessary to choose a site even farther still from the sources of the tributaries. It may even appear, that no such site exists on any of the smaller tributaries. And thus the future surveys may be materially limited in their scope. And perhaps, without further surveys, the question may be *settled*, whether numerous small reservoirs or a few large reservoirs, may be the proper plan of any system of artificial reservoirs. But, in the present stage of our investigation, we confine ourselves mainly to the general outlines laid down in Mr. Morris's paper. For the present, therefore, we pay no particular attention to the reservoir characteristics of streams below a point that will secure the available drainage of 600 sq. miles; though without granting that even at that distance from the sources, all the elements designated can be obtained. Let us look at this practically, by the light we can command.

Wheeling is the starting point; that being the place where the records

* It could not be as much as *half*, except in a case where there was no valley save the river or creek itself; and where the sides were vertical. Such a site does not exist on any of the head-waters of the Allegheny River.

of the height of the river and the measurements of its flow were made, upon which the reservoir plan as yet stands.

It is not very important that the tributaries flowing into the Ohio between Wheeling and Pittsburgh should be critically examined, now, or at any time, for the reason that if the reservoir plan should be adopted, the artificial supply must enter as high as Pittsburgh ; the water failing there as much as at Wheeling in dry seasons, with a more rapid fall per mile. We will, however, briefly refer to the principal tributaries entering below Pittsburgh.

On the left or east bank occur, Short Creek, Cross Creek, Raccoon Creek, and Chartier's Creek. The largest, Chartier's Creek, drains an area of only about 300 square miles ; so that even with a dam at its mouth, it would only secure half enough for one reservoir. Raccoon Creek, the next in size, drains only about 160 square miles.

On the right or west bank occur, Wheeling Creek, Short Creek, Yellow Creek, Little Beaver River, and Big Beaver River.

Little Beaver River drains about 400 square miles. Yellow Creek about 200 square miles. The Little Beaver runs through a narrow valley, with but occasional bottom lands on the lower 20 miles of its course. New Lisbon, the capital of Columbiana County, Ohio, is situated on this stream, 25 miles from its mouth measured along its windings. Below New Lisbon, it rises at the rate of about 8 feet per mile ; above New Lisbon it rises still more rapidly. The best place for a high dam on the Little Beaver, is near its mouth. A dam 100 feet high would, however, back the water but 12 miles instead of 25, and the pool it would form would contain less than 2,000,000,000, or not more than *one-fifth* of the available drainage of even 400 square miles. A dam at the point just named, would destroy several valuable mills, but not much valuable bottom land.

We next come to the Big Beaver River, 28 miles below Pittsburgh. This is long enough, and drains territory enough to meet *one* of the requirements for a *large reservoir.* Its extreme length from its sources at the heads of the Shenango in Ohio and Pennsylvania, being 120 miles. To obtain the drainage of 600 square miles, the dam must be placed as far down the Shenango as the vicinity of Sharon. From Sharon upward towards Greenville, the stream rises 5 feet per mile, above Greenville 7 feet per mile. A dam 100 feet high between Sharon and Clarksville, would back the water about 17 miles. It would flood Clarksville, Greenville, and several valuable mills, and destroy 17 miles of the Pennsylvania Erie Canal, now the property of a private corporation ; and its pool would not contain more than one-third of the drainage of 600 sq. miles. At Greenville, the Shenango forks, and if a dam were built on either fork so as to save Greenville, it would not secure the drainage of more than 170 square miles on one fork, or 150 square miles on the other. The only resort then would be farther down the Beaver, or upon its Mahoning Branch. Taking the Mahoning, which enters the Beaver two miles below Newcastle, Pennsylvania, it will be found that to obtain the drainage of 600 square miles, the dam should be not far from Warren, the county seat of Trumbull, Ohio. A dam 100 feet high if placed below, would submerge Warren, 20 miles of the Pennsylvania and Ohio

Canal, several valuable coal mines, mills, and excellent farm land, and a number of miles of the Cleveland and Mahoning Railroad. In fact, it is inadmissible there, or at any point between Warren and Newcastle. Just above Warren, a dam would secure the drainage of 600 square miles. Whether a dam of one hundred feet height would accomplish it, is not certain, but possibly it would, as the country is comparatively flat, and at the same time well improved and cultivated. It would require a very long dam, and would destroy 20 to 25 miles of the Cleveland and Mahoning Railroad, 20 to 25 miles of the canal, and much other property, involving very heavy damages. The land damages alone would not be less than a million of dollars independently of other damages named, and the destruction of towns. The inhabitants of that region of country, would not permit the erection of such a structure. Practically, there is no place where such a work is admissible on the Mahoning branch of the Beaver.

The dernier resort, so far as the valley of the Big Beaver is concerned, would be the *main stream* between Brighton and Newcastle. There is already on that part a succession of dams forming the slackwater of the "Beaver Division," as it is called. A dam 100 feet high erected just above New Brighton, would back the water about as far as Newcastle, say 20 miles. It would form a pool that might average 35 feet deep for 1000 feet of average width in the main valley, and half as much more up the tributaries. This would make a total of 7,920,000,000 cubic feet, or less than a third of the drainage of 600 square miles. The damages would not be very heavy except the cost of the *new locks* and towing path along the new pool, in view of the old locks, &c., for 100 feet of lockage. A few hundred thousand dollars perhaps, would cover all. This is undoubtedly the only place on any part of the Big Beaver where a large dam of the kind could ever be located, and yet even here, it would not afford one-third the quantity assumed as proper to such a dam.

Above the Big Beaver no tributary of consequence enters on the western side of the Ohio until we ascend to Pittsburgh, the veritable head of the river.

Starting at Pittsburgh, let us first take the Monongahela and its branches; beginning at the head waters of the Youghiougheny, in the State of Maryland.

It is less than 40 miles from its farthest source down to the Pennsylvania State line, and not more than 350 square miles are drained in Maryland. In order to obtain the drainage of 600 square miles, a site must be chosen in Pennsylvania, probably at the passage of the stream through Laurel Hill Ridge. But the fall in this part of the Youghiougheny is 10 *feet* per mile; so that a dam 100 feet high would back the water only 10 miles, and the pool created thereby would not probably contain more than *one-fourth* of the entire drainage of 600 square miles. According to data furnished in Mr. Ellet's paper, the fall in Youghiougheny even between Smethport and Connelsville is 393 feet, which must be more than 10 feet per mile. It is evident, therefore, that the Youghiougheny is not favorable for the establishment of one of the contemplated large reservoirs, unless it could be located towards its mouth, along the present slackwater navigation. In that event, it would of course involve the con-

struction of 100 feet lift of new locks, besides the submerging of several towns, mills, coal banks, and other valuable property. None of the *tributaries* of the Youghiougheny would afford a site having any thing like the adequate extent of drainage.

We next proceed to the other head waters of the Monongahela. Take *Cheat River*, which enters the main stream within Pennsylvania, a few miles below the Virginia State line. It is a Virginia stream. In regard to this branch of the river, Mr. Ellet states, that in the first forty-seven miles above its junction with the West fork it falls 600 feet, or 13 feet per mile. It is obvious, therefore, that this will not meet a requirement based on a fall of only 4 feet per mile; and that a hundred feet dam, instead of backing the water 25 miles, could only flow 8 miles; and that the quantity likely to be stored in such a pool, would fall very far short of the quantity assumed by Mr. Morris.

Next comes the West fork or main Monongahela River, also, a Virginia stream until it enters Pennsylvania, about ninety miles from Pittsburgh. The fall of this steam from Weston in Virginia, to the forks above mentioned, is only about two feet per mile. From the remarkable fact that the Monongahela River even so near to its head has so little fall, it may fairly be inferred that here is a favorable site for one of the proposed large reservoirs.

The Monongahela Navigation Company would, it is to be presumed, favor and perhaps aid the construction of a large reservoir on the head waters in Virginia, as it would relieve them from the difficulty they now labor under in dry seasons for want of a sufficient supply of water. If made large enough to aid essentially in improving the navigation of the Ohio River, it would afford hydraulic power on the Monongahela of some value. The question yet to be determined on the Monongahela will be the proper location and probable cost of the structure necessary to form the reservoir. For this the writer does not possess the data. But its erection would involve the necessity of some efficient and convenient arrangement for passing the rafts and other descending craft of a body of owners and dealers jealous of their navigation and hydraulic rights and privileges.

Leaving the Monongahela, we will now proceed northward up the Allegheny, which is the main prolongation of the Ohio; taking first the right bank or west side, and dwelling but little on tributaries which drain only a small area of country. The first considerable tributary is Bull Creek, which enters just below Freeport, 27 miles above Pittsburgh, and that drains only 150 square miles. There is none even as large as Bull Creek, until we reach French Creek, 130 miles above Pittsburgh. The Allegheny River at the mouth of French Creek is 261 feet above the river at Pittsburgh, showing an average descent of 2 feet per mile on the whole distance.

French Creek is a very important tributary of the Allegheny River. It was gauged during the summer of 1839, under the direction of the writer, by James Worrall, Esq., Civ. Eng., and found to yield in round numbers 22,000 cubic feet per minute. It was a low stage, but not by any means its very lowest stage, but probably affording a fair criterion of its flow in *ordinary low* water. This stream rises within less than eight miles

of Lake Erie, in Erie County, Pennsylvania, and in Chatauque County, New York. Near its head, the country is comparatively flat. A point 40 miles from its sources, would be near Meadville, above which flourishing town, the well known capital of Crawford County, a dam could be built which would be below the drainage of 600 square miles. The fall in French Creek for a distance of 15 to 20 miles above such point, is 4 feet per mile. A dam 100 feet high would therefore flow the water back about 25 miles; and, from the shape of the valley, it might perhaps hold half of the drainage of 550 square miles, which is about the area drained by French Creek above Meadville, leaving out, of course, the drainage of Cassawaga Creek, which enters below where the dam could be built. Such a high dam would submerge several mills, several towns, numerous roads and houses, and much excellent and well improved farm land. If constructed, it would be necessary to furnish from its pool sufficient water for the supply of the French Creek feeder, a navigable canal 22 miles in length, and for 45 miles of the Conneaut line of the Erie canal, and 10 miles of the Shenango line, all of which being 77 miles of canal, are now *wholly supplied* from French Creek, from Bemus' Dam 2 miles above Meadville; and none of which supply returns again to any part of French Creek. The flow is about 7260 cubic feet per minute for about 8 months of the year; assuming the area to be 75 square feet, and the rate 1·1 miles per hour, where it passes the aqueduct. It may be, that the water power leases may require this flow for the entire twelve months. In that case it would take 50 per cent. more, and the total quantity would be for a year, 3,750,000,000 cubic feet.

Again, French Creek falls between Meadville and Franklin, (the capital of Venango County, at the mouth of the Creek,) 30 miles, at the rate of about 4 feet per mile, so that a dam 100 feet high would flow back 25 miles. But if built below and yet within 20 miles of Meadville, it would submerge it. It would also back the water up the Conneaut outlet, and overflow Conneaut Lake, and waste part of the water into the Shenango Valley, running southward into the Big Beaver River, and part into the Conneaut Creek, running northward to Lake Erie; for it is a curious fact, that the water from French Creek, which naturally belongs to the Ohio Valley, now forms the sole supply of 45 miles of the northern end of the Pennsylvania Erie Canal, and empties into the Lake at Erie. To admit of a 100 feet height of dam, the structure must be located within two or three miles of Franklin. Here the valley is more confined by tolerably steep hills, and the quantity that could be stored in a reservoir would be very much less. The damages would also be less, but still they would constitute a heavy bill of expense. Therefore, although theoretically there is a reasonably good site for *one* of the great reservoirs on French Creek, practically there are serious difficulties to be encountered and overcome. And at the best, no single dam of 100 feet height on French Creek would contain more than half the drainage of 600 square miles.

The next tributary of considerable size above French Creek, is Oil Creek; but it drains an area of only about 270 square miles. It falls 4 to 5 feet per mile.

Next in order is Brokenstraw Creek, draining only about 240 square miles.

Then comes the Connewango Creek, entering the Allegheny at Warren, the capital of Warren County, Pennsylvania. This Creek drains about 960 square miles, including Chatauque Lake, in Chatauque Co., New York. To secure the drainage of 600 square miles, the dam should be put not farther down than Frewsville, which is about 15 miles above Warren. The distance from Chatauque Lake to Warren, following the course of the Cassadaga and Connewango Creeks, is about 29 miles, and the fall 119 feet, or about 4 feet per mile. A dam near Frewsville, 100 feet high, would overflow Chatauque Lake about 40 feet; which it is presumed is not admissible. It would, therefore, have to be located within 4 or 5 miles of Warren, across the main Connewango Creek. Not being personally acquainted with this stream, no further remarks in relation thereto will be made in this place. Possibly it may be favorable.

Above the mouth of the Connewango, there is no tributary of the Allegheny on the same side, whose area of drainage would approach the requirement of 600 square miles, or even half of it.

Returning to Pittsburgh, we take the left or east bank of the Allegheny River. Between Pittsburgh and Freeport, 28 miles, no tributary enters which drains more than about 50 square miles.

Just above Freeport, we meet the Kiskiminetas River, second only in importance to French Creek, in its extent of drainage and supply of water to the main river. It is over 100 miles long, and its sources are on the western slopes of the Allegheny Mountain, in Cambria and Somerset Counties, Pennsylvania. Forty miles from the most remote head of the Stony Creek branch, would extend below Johnstown, and as far down as the passage of the Conemaugh* River through *Chestnut Ridge*, a spur of the great Allegheny chain. A dam at Chestnut Ridge, would be below the drainage of about 700 square miles. But a dam built there, would be of great height if required to form a pool of sufficient size to contain the drainage of 600 square miles, as the valley is narrow, and the hills steep, between Chestnut Ridge and Laurel Hill, and for most of the distance from Laurel Hill to Johnstown; and the effect of such high dam would be to submerge Johnstown, the Pennsylvania Central Railroad, the State Canal, the State Railroad above Johnstown, and the Cambria Iron Works; in which latter more than a million and-a-half of dollars are invested. It would, besides, destroy a large amount of other valuable property. It may, therefore, be regarded as *impracticable* at any point that would flood Johnstown.

At Johnstown, the stream forks, this being the junction point of the Conemaugh River and Stony Creek. On the Conemaugh, or rather a branch of it, a reservoir has been constructed for the purpose of supplying the western division of the Pennsylvania Canal in dry times. It was built by the State, under the direction of Wm. E. Morris, Esq., Civil Engineer. It is said to contain 466,000,000 cubic feet of water, and to have cost $166,000. The Conemaugh Reservoir is entirely out of the

* Above the mouth of Blacklick Creek, just below Blairsville, the name of the main stream is Conemaugh, below that, Kiskiminetas.

way of injuring the public works; its location being south of the old Allegheny Portage Railroad. Whereas, owing to the location of the Pennsylvania Central, and the new State Railroad, in the immediate valley of the Conemaugh, all the way from Johnstown to its head, no large reservoir could possibly be permitted in this stream above Johnstown.

Stony Creek remains. The entire drainage of Stony Creek, and all its branches, is only about 400 square miles, or but two-thirds enough for one of the proposed large reservoirs. If, therefore, a dam were thrown across it near its mouth, in the vicinity of Johnstown, it would not hold the drainage from more than 300 square miles, unless it were more than 100 feet high; and the damages to mills and improved property would be heavy.

Turning to the Conemaugh below Laurel Hill, and above Blairsville, we can find a point where a dam 100 feet high could be erected without very heavy damage to private property, because the valley is very narrow, and the side hills generally steep; but it would submerge a portion of the PennsylvaniaRailroad, and involve the building of 10 or 12 new locks on the Pennsylvania Canal, and a very complicated arrangement that would permit the pool to be emptied for supplying the Ohio River, without seriously incommoding the *canal navigation*. But owing to the contracted width of the valley, and the amount of fall in the stream, the pool would not contain one-third of the drainage of 600 square miles.

Below Blairsville, the principal tributary of the Kiskiminetas, is the Loyalhanna, a fine stream, but draining only about 300 square miles. A very high dam at or near its mouth might control the drainage of that area, but the damages to valuable farms, buildings, and mill property would be very great.

Blacklick Creek, the only other remaining tributary worthy of notice, entering the Kiskiminetas below Blairsville, drains somewhat less than 300 square miles.

We then come to the main Kiskiminetas River, the fall in which is about 4 feet per mile. A dam 100 feet high would therefore flow back about 25 miles. The valley at the height of an average of 50 feet above the present low water, would be about 1200 feet wide. Such a reservoir would probably contain, including the flow back along the tributaries, about 8,000,000,000 of cubic feet, or not quite one-third of the requirement for one of the large reservoirs; and about one-half of the drainage of 600 square miles, allowing 12 inches per annum as available. It would require the construction of 100 feet vertical of new locks, or 10 locks of 10 feet lift each, and some new and peculiar arrangement to allow for the gradual drawing down of the pool, so as to maintain the canal navigation as the water should be discharged for supplying the Ohio River. It would submerge 20 or more miles of the "North Western Railroad," and destroy not less than twenty valuable salt wells, several considerable towns—Leechburg, Warren, Saltzburg, or at least two of them, and several very valuable water-powers. The damage to landed property would not be heavy. The dam would have to be located far enough above the mouth of the Kiskiminetas, to leave room for the North Western Railroad to be rebuilt on a new route with a moderate grade, as in the vicinity of the dam the railroad would ne-

cessarily have to be about 110 feet above the present surface of the water. This would make the new route of the road much more costly than the old one, on account of the expensive crossing of the tributaries at a higher level.

Leaving the Kiskiminetas, we come to Crooked Creek, which drains only about 280 square miles, and enters the river a few miles below Kittanning. Its valley is narrow, and it has a rapid fall, and is not well adapted for the purpose of a single large reservoir. Next is the Cowanshanoc, which enters a short distances above Kittanning. It does not drain over 75 square miles, and falls more than 10 feet to the mile.

Next above is the *Mahoning*—a fine stream, draining nearly 400 square miles. Its valley is very narrow, and bounded by steep side hills. Its average width at the height of 50 feet above low water, is not more than 600 feet; and it falls so rapidly (8 feet per mile), that a dam even at its mouth, 100 feet high, would not back the water more than about 12 miles.

Next we have Red Bank, another fine stream. This drains about 650 square miles. Its valley is rather wider than that of the Mahoning. Between its mouth and the town of Bethlehem, it may average, at 50 feet above low water, 900 feet wide. It falls here at the rate of 7½ feet per mile; so that a dam at the mouth, or any where between the mouth and Bethlehem, 100 feet high, would flow back only about 13½ miles. Such a pool would probably contain about 3,300,000,000 cubic feet, or about one-sixth of the drainage of 600 square miles Above Bethlehem the valley is wide, and the country well improved. A dam on the stream above Bethlehem would hold more than one below, but it would lose part of the drainage, and the damages would be much heavier.

Both the Mahoning and Red Bank, which are navigable for descending craft, and out of which an immense amount of lumber and timber is annually rafted, would have to be arranged so as to secure the safe passage of rafts, &c. A dam above Bethlehem would also submerge the located track of the Allegheny Valley Railroad. Above Brookville, which is the capital of Jefferson County, the stream has more fall, and becomes less and less advantageous as reservoir ground; the heads of the streams falling more than 30 feet in a mile.

We come now to the Clarion River, about 85 miles above Pittsburgh. This is the largest tributary above the Kiskiminetas on the same side, and drains about 1400 square miles. From the town of Clarion, the capital of Clarion County, down to Callansburg, near the mouth of Big Licking branch, it has a fall of 6½ feet per mile, with an average width of about 200 feet, and as high as Ridgway, the capital of Elk County. Above Ridgway it forks, and both forks have more than 7 feet fall per mile, until within a few miles of their heads, where they are quite abrupt, falling off more than 50 feet per mile. A dam to secure the drainage of 600 square miles, should be located as far down as Ridgway. In order to save Ridgway it would be necessary to place the dam, if built 100 feet high, about 15 miles below Ridgway, or farther. The valley of the Clarion River, between Ridgway and Clarion, is generally quite narrow. On much of the distance there is scarcely any bottom land, and the hill sides are tolerably steep; but not so steep as on the Maho-

ning. At the height of 50 feet above low water, the average width may be 1000 feet or rather more. Assuming it to be even 1200 feet, the pool of a dam 100 feet high, would hold about 5,300,000,000 cubic feet, or not quite one-third of the drainage of 600 square miles, 1 foot deep.

A dam *above* Ridgway would not catch the drainage of more than 250 square miles, and if built 100 feet high, it would not hold more than half of that drainage on account of the rise in the bed of the stream, and the shape of the valley; the rise from Ridgway up, being at first 7 feet per mile, gradually increasing to more than 50 feet per mile. It is probable, then, that the most advantageous site for a large reservoir any where on the Clarion waters, will be found between Clarion and Ridgway where the fall is about 6¼ feet per mile. But there is no point on the entire river where a single dam 100 feet high will back the water 25 miles, or be likely to form a reservoir holding half of the quantity required for one of the large reservoirs.

Next comes the *Tionesta*, about 35 miles above Franklin, which with its Raccoon fork, drains about 500 square miles. The Tionesta is much more rapid than the Clarion, and runs for the most part through the wildest region of Pennsylvania, in the shades of deep and steep gorges. Although damages on this stream would be an unimportant item, the contracted width of the valley, and the abrupt declivities of its sides would make costly reservoir work, if attempted on the large scale. Ascending the stream in search of a favorable location will be useless, as the ascent increases until its upper waters rise more than fifty feet per mile.

Next is the Kenjua Creek, of very similar general features, but draining only about 200 square miles, and not favorable for large reservoirs.

The last tributary of the Allegheny River, on the same side, deserving notice in this connexion is Potato Creek, and this drains only about 150 square miles. A high dam could not be built at its mouth, for two reasons: because the valley is very wide (nearly a mile, much wider than any part of the main river valley below Olean), and because it would submerge Smethport, the capital of McKean County, Pennsylvania. If built above Smethport, it would not drain more than 80 square miles. The Potato Creek is remarkable for its *wide valley* and very *slight fall*—only about 2 feet per mile from its mouth for 13 miles up; but as it gradually decreases in width towards its upper end, the fall in the stream becomes very abrupt like the other head waters.

Having thus traced the general characteristics of all the tributaries of the Allegheny River, approaching in extent of area drained the dimensions necessary for large reservoirs, let us now look at the main stream itself. Beginning at Coudersport, the capital of Potter County, Pennsylvania, which is within less than 10 miles of its extreme sources, we should secure only about 70 square miles; and here the main valley is much narrower than it is a few miles farther down, and the river descends rapidly; too much so for the economical saving of water on a large scale. We should be forced down as far as the mouth of Potato Creek, before we could command 250 square miles of territory for drainage. Even at the State line, where the river first enters New York,

there would be but 500 square miles, including all of Potato Creek drainage. In two respects, the vicinity of the State line is advantageous as a site for a high dam; the hills approach each other within about half a mile, and the valley soon *widens out* above the line, and the fall in the main river is only about 2 feet per mile; but unfortunately a dam less than half of 100 feet in height would flood *Smethport*, Eldred, Kingsville, and numerous dwellings and fine farms, besides several important mills.

This flat-place, as it may be termed, in the Allegheny River, is a very peculiar feature, to which particular reference was made in one of the writer's reports a few years since. The course of the river for about 10 miles is almost due north, whilst its general direction is south. In an engineering view, the point at the State line presents as favorable a site for the erection of a large dam for a reservoir as *any* above Wheeling; but even here, it could not catch the drainage of over 500 square miles.

The lumbering interests along this part of the Allegheny River, are *very important*, and cannot by any chance be overlooked in considering any reservoir arrangements. Proper provision would have to be made for the safe and convenient passage of a heavy trade in which nearly every individual in the region is in some manner associated. As secondary to this, it may be proper to mention that the Allegheny Valley Railroad is located along the bottom land between the State line and Smethport, and also, that a company has been incorporated to construct a slackwater navigation, designed chiefly for the great coal field of McKean County.

But before proceeding farther down the main river, let us briefly recapitulate the results of the foregoing preliminary investigations among the tributaries.

Capabilities of the Tributaries for Large Reservoirs.

It would appear, that excluding for the present, sites on the main rivers Ohio, Monongahela, and Allegheny above Wheeling, the following tributaries drain area of country enough to cover one of the requirements, namely, 600 square miles. *First*, the Big Beaver River, which as it enters below Pittsburgh, is of little or no account in connexion with the present investigation. *Second*, the Youghiougheny river which will furnish a site for a dam 100 feet high; but on account of the great fall in the stream at any point where such a dam would probably be admissible, the pool would not be likely to contain one-fourth of the assumed drainage. *Third*, the upper part of the main Monongahela river; this will probably furnish one good site. *Fourth*, French Creek; on this a dam 100 feet high could be erected, as herein described, but it would not contain more than half of the required quantity. *Fifth*, the Connewango, which may possibly afford a favorable site. *Sixth*, the Kiskiminetas river; although this drains ample territory, there are serious obstacles, as we have shown, in the way of erecting a large dam anywhere on this stream; and nowhere can the erection of a dam of 100 feet height secure the quantity of water assumed. *Seventh* and last, is the Clarion River; and upon this, from the data known, it is almost cer-

tain that a 100 feet dam will not create a pool sufficiently large to contain one-third of the drainage of 600 square miles. Above Pittsburgh, then, independently of the site referred to on the main river Monongahela, in Virginia, there are but five streams that drain 600 square miles; on not one of which is there any reasonable probability that a dam of 100 feet height would form a pool of such size as would contain the drainage of the area named, even estimating at an average of 12 inches, instead of 18 inches, as assumed by Mr. Morris. Either a greater number of dams, or much *higher* structures than the highest yet contemplated must be employed.

The writer is led to infer, that neither Mr. Ellet nor Mr. Morris, in advocating the construction of feeding reservoirs, had taken time to look into the probable practical result of their construction at any *particular points*. Mr. Morris says, "can we find six reservoir sites upon as many creeks, each draining a basin equivalent to 40 miles long by 15 miles wide?"

"Can proper locations be found at the lower ends of these basins for the *six* dams necessary to form six lakes, commanding each a drainage of 600 square miles? Or for a greater number of lakes of equal aggregate capacity."

"For the present, we will assume (what we do not doubt), that *six* suitable sites can be found, and that six dams can be erected, *each* ponding back, or giving an annual available capacity of 25,000 millions of cubic feet of water."

Yet the facts, so far as they can be given approximately without further careful surveys, go to prove that no such sites exist on the creeks. Again, Mr. Morris gives the dimensions of "The Saint Ferrèol Reservoir, built in 1667, the oldest large reservoir is existence, as follows:—(Andreossi's Histoire du Canal du Midi.)

Water raise,	= 103 feet.
Height of dam,	= 107 "
Length "	= 2558 "
Thickness at base,	= 394" "

Truly, an immense structure, and which cost an immense sum. Now how much water does that reservoir contain? Does it contain anything like the quantity of water allotted to one of the Ohio River reservoirs? Mr. Morris refers also to the reservoir constructed by William E. Morris, Esq., Civ. Eng., on the western side of the Allegheny Mountains, which has 62 feet water raise, and yet it only contains 466,000,000 cubic feet. It would require 53 *such reservoirs* to fill *one* of the size proposed by Mr. Morris.

With facts like these, it is not difficult to arrive at quite a different conclusion as to the facility of finding on the tributaries referred to, the elements necessary to sustain Mr. Morris in his assumed data. It seems to be tolerably clear, that if dependence is placed upon reservoirs on the tributaries, that a much greater number of reservoirs of much smaller capacity must be adopted.

Leaving the consideration of reservoirs on the tributaries, let us turn our examination to the main rivers, and test the results likely to be attained from dams of 100 feet height thrown across them where they are

navigable—navigable in the ordinary adaptation of the term, for example, below the Virginia State line on the Monongahela, and below Olean on the Allegheny. We will take the Allegheny river immediately above Franklin; of course there is no question here, respecting the sufficiency of the drainage; and a reservoir would be different from the proposed reservoirs upon which Mr. Morris bases his calculations in this; that draining a much larger area of country than would be sufficient to fill it, it might, to a *certain extent*, be employed as suggested by Mr. Ellet, as a regulating reservoir.

Above Franklin, the river has a fall of about 3¼ feet per mile. A dam 100 feet high would back the water about 30 miles. The principal streams flowing in on this distance, are Oil Creek, about 7 to 8 miles up, and Tionesta, about 25 miles up. The pool would be about 75 feet deep at the mouth of Oil Creek, and 17 feet at the mouth of Tionesta. It might back up Oil Creek about 15 miles to Titusville; and up the Tionesta not over two or three miles. It will also flow up a number of smaller tributaries, but not generally very far, on account of their rapid fall. We will take liberal dimensions representing the sloping or descending river valley that the pool is to cover, and assume that it shall average

500 feet wide,	50 feet deep,	River.
500 "	30 "	Bottom land.
90 "	15 "	Slopes.
150 "	25 "	"

on the whole distance of 30 miles. This would give in round numbers for the main valley 7,043,840,000 cubic feet; allowing on Oil Creek valley half the average area given on the main stream with half the length, it would give quarter, or 1,760,960,000 cubic feet; the flow up Tionesta would be in round numbers, say 50,000,000 cubic feet. Above the Tionesta the flow in the tributaries would be comparatively trifling, and between Oil Creek and Tionesta, the streams are short and the backwater would not extend very far, but, allowing even one-third as much as in the main valley, it would give 2,337,980,000 cubic feet. The sum would be 11,202,780,000, or considerably less than half of the quantity assumed for one of the large reservoirs proposed, say in round numbers just half.

A second dam thrown across the main river at the upper end of the pool, would, if raised 100 feet, flow to within about 10 miles of Warren.

The *two* might possibly contain 25,000,000,000, the quantity required for one of the proposed large reservoirs. Immediately above Warren, a third dam of 100 feet height might be placed; and as the fall in the river is there about 4⅓ feet per mile, it would flow back about 23 miles to the vicinity of Indian Village, and would contain not exceeding three-fourths of the quantity due to the lower dam.

A fourth 100 feet dam, located at the upper end of the third pool would reach to within a few miles of Olean, and might contain about the same as the third. The capacity of the four would be equivalent in round numbers to 43,750,000,000 cubic feet, or about one and two-thirds of a single large reservoir of 25,000,000,000 described by Mr. Morris.

The entire drainage above Franklin, is in round numbers 4000 square miles, and allowing 12 inches per annum as the available surface drain-

age, the total quantity would be 111,513,600,000 cubic feet, or a little more than three and a half times the capacity of these four great reservoirs. This shows most strikingly the immense bulk of water to be dealt with. Here are four enormous reservoirs, covering one hundred and six miles in length of the main Allegheny River, which will probably contain less than enough to fill *two* such reservoirs as are used in Mr. Morris's calculations.

If the 100 feet dams were placed in the Allegheny River below Franklin, they would create more extensive pools, at the same time the damage to property would be greater. Still one above Brady's Bend, which would back up the Clarion River some miles, would probably contain considerably more than either of those suggested higher up the Allegheny.

Let us now turn to the main Monongahela below the Virginia State line. It will perhaps be admitted, that it is not feasible to build a dam of 100 feet high at any point below Brownsville, for the reason that from the present low water surface at Brownsville to the Ohio River at Pittsburgh, the *total fall* is only 36 feet. If erected just above Pittsburgh, it would therefore raise the water 64 feet at Brownsville, and 82 feet at the mouth of the Youghiougheny. It would destroy so many and such large interests, that we think it may fairly be considered to be out of the question.

The fall between the Virginia State line and Brownsville, 35 miles, is 42 feet. A dam 100 feet high at Brownsville, would therefore flow back about 25 miles into Virginia, and make a depth of 58 feet over the river bed at the State line. Assuming that in the whole distance of about 67 miles, the pools along the main valley should average 800 feet with a depth of 40 feet, and that as much more (which is deemed liberal,) would flow back along the tributaries, the entire pool would contain 23,654,400,000 cubic feet, or say, in round numbers, enough to fill *one* of the proposed large reservoirs.

The writer believes that with the four dams on the Allegheny, and this one as described on the Monongahela, properly managed, a constant flow of not less than 5 to 6 feet could be maintained in the Ohio River at Pittsburgh and at Wheeling; and further may add, that ever since he first roughly tested Mr. Ellet's theory, his opinion has been, that if the river is ever to be maintained at a comparatively steady stage of navigation—that is, constantly above some given number of feet in the channel, without dams on the main Ohio, it would be by means of a *few dams* on the main rivers, in preference to many reservoirs near the heads of the streams, so far as *first cost in building dams* would be concerned. But he has always apprehended that great practical difficulties would attend the carrying out of the plan in either case—that is, either with the few great dams on the main rivers, or the numerous small reservoirs higher up. The present approximate investigation, as it may be called, tends to confirm this opinion.

It may be remarked in this place, that the theory that these large dams may be made to constitute a part of a regular slackwater navigation, as suggested by Mr. Ellet, is certainly fallacious. They may be made to form a part of a descending navigation. On a little reflection it must strike every one, that so soon as a few feet should be drawn down from

the surface of one of these dams, it would leave the upper end of the pool bare, except so far as *a flow* of water might be kept up by water drawn from the dam above. It would create a slackwater of a peculiar character, and require a peculiar and novel arrangement for locking rafts, arks, &c. from a pool which at different periods of the season, would present a variation of nearly one hundred feet in its height of surface. Such arrangement, whatever it may be, would, without question, be regarded as inadmissible on the main Ohio, or on any part of the Allegheny or Monongahela rivers, maintained, or desired to be maintained, as a respectable slackwater for ascending and descending trade.

Mr. Morris, in the Appendix to his paper before alluded to, referring to high dams and the anticipated difficulty of accommodating the lumber trade, &c., remarks "once collected within the pools of the reservoirs, both logs and lumber would be floated from them *through the reservoir dams*, at periodic seasons by means of substantial contrivances, which any skilful engineer charged with these works will know how to plan, construct, and operate with entire success." We know not what particular arrangement may have been in view; but if any plan could be devised satisfactory to those interested in the descending navigation of the Allegheny and Monongahela, which would dispense with the *lockage* at the high dams, it would greatly strengthen the *reservoir plan.*

Mr. Morris has given an estimate of the cost of one of the proposed large reservoirs, which does not however include anything for locks. His estimated cost " for one dam is $2,000,000. Total for the six artificial lakes, say 12,000,000 dollars." This may be quite enough for the number and kind of dams assumed, but is it enough to secure the quantity of water estimated to be stored? The estimate is based on the general idea entertained by him that those large reservoirs could be established on the *creeks* towards the heads of the streams, the damages being estimated at only $10 per acre; whereas, it is obvious that such high dams cannot be profitably located there on account of the rapid fall encountered. And Mr. Ellet says in his paper published in 1849, in the Appendix, "There is no difficulty on any of the principal tributaries of the Upper Ohio, in obtaining reservoirs capable of holding from twelve to twenty thousand millions of cubic feet. It can scarcely be doubted that *twelve* or *fifteen* sites for dams may be selected capacious enough to hold all the excess of water, and equalize the annual discharge so nearly that the depth may be kept within a very few feet of an invariable height." The writer apprehends that surveys will establish a very different result.

But waiving for a moment the consideration of the cost of storing up water by means of high dams or great reservoirs, if we take the Conemaugh reservoir before mentioned, as a criterion of the cost of procuring water, we have 466,000,000 cubic feet, costing $166,000. The quantity estimated by Mr. Morris being 150,000,000,000 cubic feet, at the same rate per cubic foot it would be $ 53,410,000, and it would require 321 reservoirs of similar size.

But in the case of the few large dams on the main rivers, the cost, including locks for the 100 feet lift at each dam, would probably be much less. The actual first cost is, however, not the only important question. Some adequate and satisfactory arrangement for the passage of the im-

mense descending lumber trade must be provided. Can it be accomplished with dams of 100 feet height, either by means of locks, or in any other manner, in such a practical shape as to be satisfactory to the parties interested? If not, then this objection will be fatal to the plan of placing these immense structures on the main river Allegheny.

In the absence of any definite suggestion respecting the *mode* of overcoming this great practical difficulty, the advocates for artificial reservoirs may be obliged to fall back upon the original proposition of Mr. Ellet—numerous smaller reservoirs towards the sources of the tributaries. Then if we take but one *half* the cost per cubic foot of water, as just calculated, it would amount to $26,705,000.

Is it reasonable to presume that the quantity designated, 150 thousand millions of cubic feet would cost much less?

There can be no doubt that there are several advantages appertaining to large reservoirs on the main streams, where the retained water is to be used for navigation purposes, in commanding surplus water at a lower cost per cubic foot, and in the saving of evaporation. The loss by evaporation from the greater surface of numerous small reservoirs, and on many miles during its flow from those distant points to Pittsburgh would be very considerable, and should not be overlooked in any future critical examination. They could also be more cheaply managed than numerous smaller ones.

Three hundred and twenty-one reservoirs, each as large as that on the Conemaugh, allowing an available drainage of 12 inches depth, would require for each, an area of territory of 16·7 square miles, and an aggregate of 5360 square miles. This would bring into requisition "sites in or near the elevated country," but it will be impossible to avoid encountering in nearly every instance, much more rapid fall than "four feet per mile," and a much less average width of valley than "three-fourths of a mile;" and no where will the depth of a reservoir average half the greatest depth at the dam. Nearly all the head waters within five, and most of them within ten miles of their sources fall 30, 40, or 50 feet, or even more per mile.

It is proposed to examine next, the effect of great reservoirs on the main tributaries or rivers, in connexion with high floods, &c.

Great Reservoirs; their Control of Great Floods.

We proceed to examine the effect of reservoirs on the Allegheny River, &c., in connexion with the great freshets of the Ohio River.

Mr. Ellet has suggested, and to a certain extent elaborated the idea, that it is entirely practicable at an allowable and reasonable cost, to construct large reservoirs on the main branches of the Ohio, or on the Allegheny and Monongahela rivers, which shall give us complete practical control of heavy freshets. He says, "It is not asserting more than the measurements presented in this paper will justify, when it is maintained that it is entirely in the power of man to control all the waters of the Mississippi and Missouri, and compel every river to flow with an even current, from its source in the Allegheny or Rocky Mountains, to its home in the ocean, forever free from the hurtful effects of floods and draughts."

"Reservoirs may eventually be made of sufficient capacity to hold all the annual excess, and make the daily flow almost entirely uniform."

"All this may be accomplished on the Ohio *for about the cost of three or four ships of the line.*" "The great and only difficulty is to overcome the cold incredulity of the public, so as to induce those in power to grant a sufficient appropriation for the completion of the first two reservoirs." The italics are in Mr. Ellet's original paper. Again, "to exercise complete control over all injurious floods, will involve a greater outlay than will be required for the effectual improvement of the navigation; but even this can be accomplished by works which will also secure to the navigation a permanent depth of *six feet, for about the cost of maintaining a ship of the line on a three years' cruise.*"

Mr. Ellet's deductions satisfied his judgment, that the records, measurements, and calculations justified these premises. Mr. Haupt, possibly, without a very critical investigation, seems to sanction to a considerable extent the same attractive idea; and Mr. Morris urges that "six artificial lakes of the size herein contemplated, could not fail to exert a *material influence* in moderating the Ohio River floods." And he introduces the name of Professor E. D. Mansfield, the accomplished Editor of the *Railroad Record*, as greatly strengthening the claims of Mr. Ellet's views to public consideration.

In order to test the question of controlling floods, we propose to go beyond the suggestions of the originator of the proposition in regard to the number of large dams to be employed; and to place the first dam at Wheeling, on the main Ohio River,* and assume that a set of dams, one backing the water to the next above, each 50 feet high are built. If we take 16 dams overcoming a total rise in the Ohio and Allegheny rivers of 800 feet, they will extend 333 miles, or to within five miles of Olean in the State of New York.

The average length of each pool will be 20¾ miles. To be liberal, we assume the average depth above the river, the bottom lands, and side slope of the hills overflowed, at 40 per cent. of the full depth at the dam, or 20 feet; and the average width of the prism of water, at 2200 feet; and add one-third to the total quantity for the flowage or backwater up the tributary side streams. The entire cubical contents of these 16 great reservoirs would thus be 103,150,080,000 cubic feet.

If we allow 12 inches out of an annual fall of 36 inches of water to be available, this would equal about *one-eighth* of all the drainage of 25,000 square miles, which is in round numbers, the area of the territory drained above Wheeling.

Such a flood as that of 1832, which raised the river at Wheeling to 44 feet, would, if continued, fill all these great reservoirs, if *empty at the start*, in three days.

A fall of *two inches* of rain on a frozen surface, would also be sufficient to fill them.

The discharging capacity of the reservoirs, designed to keep up a perennial flow in the Ohio of not less than six feet depth, according to Mr. Ellet's data is 1,164,000,000 cubic feet per day.

* We are not now considering questions of damages, but simply the effect of large dams and reservoirs on floods.

This is an immense body of water, equivalent to the entire contents of 2½ such reservoirs as that on the Western Division of the Pennsylvania Canal, which holds 466,000,000 cubic feet. That is, two and a half such reservoirs must be emptied daily, to create such flow of 6 feet.

It is obvious that these 16 reservoirs, being once filled, even with the discharging pipes purposely left open, will only begin to draw down the surfaces of the pools, when the regular natural drainage into them from the daily flow shall become less than 1,164,000,000 cubic feet; and that then the daily decrease of water held in reserve, will be only the *difference* between such natural flow and the daily discharge.

The inflow never entirely ceases; but, excluding the inflow, these 16 pools would hold enough for 88 days of six feet navigation. Adding thereto the *minimum* daily flow at Wheeling, as given by Mr. Ellet, or 207,360,000 cubic feet, it would make 16 days more; making a total of 104 days. Though it has never occurred, and it is scarcely possible that such minimum flow should continue strictly for one hundred days. Such a state of the water would present a draught far greater than any hitherto experienced in this region.

This goes to prove the capacity of these reservoirs for keeping up a six foot navigation in the river during most seasons. But does it follow, that we shall have attained to the practical command of the great floods? This is the point now to be considered; and we think it may be elucidated by a closer analysis of the important and satisfactory data published by Mr. Ellet. The records, measurements, and tables prepared by Mr. Ellet, are of such a nature that they will perhaps settle this question conclusively. These daily records of the depth of the water at Wheeling begin with 1838, and end with 1848.

Before proceeding to the further examination of these records, we may presume that it will be granted, that in the case of a freshet happening at the moment when the reservoirs should be full, they could afford no aid in controlling floods below the lower dam, assumed to be at Wheeling; or at least no material aid.

We have examined these records to ascertain what the effect would have been had the above system of sixteen dams been in operation from 1838 to 1848 inclusive.

In 1838, the floods would have overflowed all the reservoirs in March, and on every day in April the inflow was greater than the discharging capacity; and for 22 out of the 30 days it was considerably more than double. In May and June, there was no day when the inflow was not greater than the discharging capacity. In May, the freshet rose on different days, to 24, 31, 29, and 26 feet respectively; and as that flood would have found overflowing reservoirs, no portion of it could have been controlled. There was not a single day for over three consecutive months, when the reservoirs would have aided in restraining large freshets. Then followed the memorable 120 days of extremely low-water, during which period the natural flow at Wheeling, according to Mr. Ellet's tables, was 26,400,000,000, which, added to the aggregate content of all the reservoirs, would have made a total of 129,500,000,000 cubic feet. The quantity required for a continuous six feet stage through the same period, would have been

139,680,000,000 which would have left a deficiency of 10,188,000,000. There would have been a little deficiency before the commencement of the 120 days. One or two large dams on the Monongahela in addition, would have supplied the entire deficiency. It is evident, on inspection, that the 16 dams would have been sufficient to have maintained over five feet depth all the time.

In 1839, seventeen days in January and eleven days in February were not recorded. We cannot therefore decide with certainty that the reservoirs would have been filled then. They would certainly have filled in March, if not before; and they could not have been materially drawn down until the first week in July. In March, April, May, and June, they could not have assisted in restraining heavy floods had any occurred. As it appears, the highest freshet was on June 16th, 23 feet. But during this period of nearly four months, the river was constantly liable to receive a first class flood.

In 1840, the record begins with January 22d. We have no present means of knowing what proportion would have been in the reservoirs on that day, and will not surmise. From that date until the end of the month, the inflow was very much more than the discharge would have been. By the middle of February, the reservoirs would certainly have been full. The first heavy flood of that month, which rose to 38 feet, might have been slightly held back, unless the flow before January 22d was heavy. But in any case, the reservoirs would have been *nearly full* before the commencement of this heavy flood; whilst the second great flood of the same month, on the 25th and 26th, which rose to 36 feet, must have found the reservoirs *largely overflowing*. Even if the reservoirs had been absolutely empty as late as the first day of February, which we know could not have been the case, they would have been filled before the 18th, before the beginning of the second flood. The flood of May 1st to 5th, which rose to 28 feet, would also have come upon overflowing reservoirs.

It is singular, that this marked exemplification of the inutility of such reservoirs as a means of controlling floods, should have escaped the observation of Mr. Ellet.

In 1841, the record begins on January 10th, when the depth at Wheeling was 22 feet. The average depth for the remaining 21 days of that month, was 14 feet, which would have half filled the reservoirs had they been empty January 9th, which, of course, could not have been the case with the water at a flood of 22 feet on the 10th. There might, or might not have been a chance of restraining, to some extent, a flood in February. In March, when the freshet of the 23d to the 31st came, the reservoirs would have been drawn down a mere trifle, and this flood which rose to 34 feet on the 29th might have been very slightly checked. From that time until the latter part of May, the reservoirs would have continued to overflow. In December, they would have been again overflowing. But during all the months of February, March, and April, or most of the time, they could not have aided in restraining floods. The highest water in April was 28 feet, and in May 20 feet.

In 1842, the reservoirs would have been overflowing in the beginning

of the year, and would have so continued until about June; offering during those five months, no protection whatever against the effects of floods below Wheeling. And *there were* freshets: in January, 22 feet; in February, two of 28 feet each; in March, 26 feet; in April, two of 18 feet each; and in May, 19 feet.

In 1843, from January 1st to 31st, there was enough inflow to fill the reservoirs; and as they would have been at least half full at the close of 1842, they would have overflowed by the first of February, and from that time until the latter end of June, nearly five months, they would not have ceased to overflow; and during all that period could have rendered no service in arresting great freshets or any freshets. The inflow during the month of April was remarkable; showing an average depth of 19·4 feet for the whole month; sufficient to have more than twice filled the reservoirs; *the whole of which* would have passed along on the top of overflowing pools. In December, the reservoirs would have been again overflowing. The highest waters were in March, 18 feet; April, 20 and 27 feet; May, 18 feet; June, 19 feet.

In 1844, throughout January, the reservoirs would have continued to overflow. In February there would have been a slight draught upon them taking about 1½ feet from the surface. In March, they would have overflowed; and they would have continued overflowing until August, when they would have been partially drawn down to keep up the required flow for August, September, and October. In November and December, they would have again filled. Thus in April, May, and June, the reservoirs could have been of no avail in restraining floods. It happened that there was no large flood in 1844.

In 1845, commencing with full reservoirs, they would have continued to overflow until near the middle of April, affording during this period of three months, no assistance in holding back freshets. The highest flood occurred March 12th, when it rose to 24 feet. This was a remarkable year along the Ohio Valley; for although it presents much the smallest total yearly flow, so that it would have made a uniform depth throughout the year of but 7·03 feet, yet it happened to be so equally distributed, that the reservoirs we are now considering, would not at any time have been emptied. The lowest average depth at Wheeling for a month, was 2·82 feet, in August; the next lowest was 3·4 feet in September. The floods were moderate, rising to 21 feet in January, and 24 feet in March; both of which would have come upon overflowing reservoirs. In December, the reservoirs would have been about half full.

In 1846, the reservoirs would have filled in January, and remained full until June, when they might have been slightly drawn upon, (though the average flow for the month of June was fully up to the quantity required for a 6 feet stage of water.) In July, they would have been overflowing. In November and December, they would have been largely overflowing. In December, alone, more than *four times* the discharging capacity would have drained into the reservoirs. On the 15th of March of this year, there was a heavy flood, which rose to 35 feet at Wheeling; but the reservoirs must have been overflowing when it came. In December, there was a flood of 28 feet, with the reservoirs overflowing be-

fore it commenced. At the close of the year, all the reservoirs would have been largely overflowing.

In 1847, a flood of 28 feet occurred, January 3d, which would have been on the top of largely overflowing reservoirs; and they would have continued to overflow for four months or more, until the latter part of May, when a *very* slight draught would have been made, leaving them overflowing again in June. In October, they would have filled again. In October, more than *three times* the discharging capacity flowed in; in November, nearly *three times;* and in December, over *six times.* In addition to the January flood, there was one in February of 27 feet; one in March of 27 feet; one in November of 32 feet; one in December of 38½ feet; not one of which could have been retarded or controlled by means of the reservoirs. In the single month of December, the inflow was more than enough to have filled all the reservoirs *twice*, had they been empty on the 30th of November, and yet we see that they must have then been full.

This was another remarkable season. The average depth for the lowest month, September, as recorded at Wheeling, was never less than 4 feet; the actual lowest water being 2¼ feet for three days. The drainage this year, would have filled all the reservoirs more than *ten times* could they have been emptied each time. The highest flood recorded in the eleven years, would have swept over the top of overflowing reservoirs.

In 1848, starting with overflowing reservoirs, they would have continued overflowing until June, with an almost imperceptible draught upon them in June, which would have been supplied again in July. Before the 20th of December, they would again have been filled to overflowing. In January, there was a freshet of 26 feet; in March, one of 18 feet; and on the twenty-fifth of December, another of 26 feet; all of which would have found the reservoirs full, and which, therefore, could not have been restrained. In December, the inflow was equal to *five times* the discharging capacity.

Thus the record for these eleven years proves, that although in a few instances, floods might have been in part checked by the operation of the reservoirs, yet in the great majority, including the *very heaviest* floods, the freshets would have passed along on their ocean bound course entirely uncontrolled. Out of thirty-two floods recorded, there were but *two* or three when the reservoirs would not have been full.

It is a fair query then, whether instead of being advantageous as means of controlling floods, they would not have been positively injurious? According to the theory of those who oppose the lock and dam system, the depth of the river below the lower dam in time of flood, would be *greater* than it would be without the dams, and this would be further increased according to Mr. Morris's suggestion, in consequence of the prism of water, six feet deep, which would constitute the lowest stage of the river. The inference would be, that the freshets below the lower dam, in a large majority of the floods, as recorded, would have been *greater* with the reservoir system in operation, than with the river left in its natural state.

It may be argued, in discussing this branch of the subject, that the venting capacity of the dams could be made greater than barely sufficient

to discharge the quantity required for a six feet navigation, the capacity allowed in the foregoing examination. True, but in reply it may be stated, that in actual practice, the real discharge in different stages of water in the pools, would *require* much more extensive apparatus than would be barely sufficient with full pools; for the reason that when they should be reduced considerably, the pressure at the pipes would be correspondingly reduced, and the discharge proportionally decreased; so that when the pools should be drawn down half the depth, or 25 feet at the dam, double the capacity of discharge would be necessary; and when three-fourths drawn down, four times the capacity, and so on in proportion as the pools should be emptied. The apparatus, with only 10 or 12 feet of pressure, would necessarily be very extensive.

But again, should it be admitted that even very much greater discharging arrangements could be employed, than any hitherto alluded to by the friends of the reservoir system, so as to give control over a larger proportion of the heavy freshets, it must be recollected, that there would be a limit to this also. We cannot overlook the *fact*, that no human foresight can divine when it would be safe to draw down the reservoirs for the purpose of *being prepared to catch a great flood*, in view of the other objects of their construction, namely, *storing up* water to be used in time of need.

Let us glance at this in another aspect; although the quantity of water calculated as stored up in these 16 dams of fifty feet height, flooding over 333 miles of a great river valley, an average depth of 25 feet above the natural surface of the stream, is but two-thirds of the quantity assumed by Mr. Morris in connexion with the six reservoirs designated by him, yet the field of operation is much more advantageous on the main river, than it would be on the smaller tributaries, for securing through the year a given quantity of water; irrespective of damages to property, towns, cities, and navigation interests. These river pools or reservoirs, would be in a much better geographical position for controlling large freshets than the reservoirs on the tributaries; because on the tributaries if they were so located as to command only about a sufficient area of territory to fill them but once during a dry season, it would not be safe to discharge *any portion* of their contents, except for *one* object, namely, to aid in keeping up the flow of the Ohio River to 6 feet depth during the dry portion of the season. If they should be emptied for the purpose of acting as reservoirs to *catch floods*, or to break the force of contemplated or expected floods, the records show that *great risk* would be run of having no water of consequence in the reservoirs when it might be *essential* for sustaining the navigation. The periods of heavy rainfalls are so entirely irregular, that the judgment of man could not regulate and bring into harmony the two things desired, upon any data that we know of or have assumed.

In order to obtain any practical, reliable control of freshets, much more extensive, and much more costly constructions would be absolutely necessary, than all that we have been considering.

It would appear, then, that Mr. Ellet's suggestions, though beautiful and desirable, are not, as he has announced, "*easily and cheaply practicable.*" That on the contrary, in regard to the great freshets on the Ohio

River, to control them practically, would require an expenditure vastly greater than he has estimated, and would involve the *destruction* of the *present* navigation of the Allegheny River; which is entirely too important to be ignored; and would come into conflict with thousands of citizens, whether in the shape of immense dams on the main rivers comparatively few in number, or reservoirs on the tributaries, smaller but greatly more numerous. But the writer does not by any means rest the question now under consideration wholly upon this latter suggestion. Nevertheless, it is a practical matter to be practically thought of.

If it is so difficult, not to say impracticable, to control the freshets of the Ohio River, how can we, as practical investigators, indulge a hope of regulating the great floods of the Mississippi? Even as high up the river as the City of St. Louis, two hundred miles above the entrance of the Ohio, and *excluding* the area drained by the entire Ohio River and all its branches, there are over *five hundred thousand* square miles of territory drained by the Mississippi and Missouri waters; being *twenty times* the Ohio drainage above Wheeling, which we have hitherto been investigating. How are we to arrest "the turbid waters of the Missouri and Mississippi, and make them to flow forever, with a constant, deep, and limpid stream?"

And how is it with the formidable suggestion, that "reservoirs may eventually be made to hold *all* the annual excess, and make the daily flow almost entirely uniform?"

We have shown the inadequacy of sixteen 50 feet dams for the Ohio River; suppose we add two more on the Monongahela, two on the Big Beaver, two on the Youghiougheny, two on the Kiskiminetas, two on French Creek, two on the Clarion, and one more above Olean on the Allegheny. Each of the two on the Monongahela might contain one-half more than one on the Allegheny, the other eleven would not probably contain an average exceeding three-fourths of one on the Allegheny. These 13 additional large reservoirs, upon a liberal estimate, might contain 70,000,000,000, cubic feet, making for the whole 29 reservoirs, 173,000,000,000 cubic feet, occupying all the main rivers and principal branches. Now, the quantity of water which flowed past Wheeling in 1847, as calculated by Mr. Ellet, was 1,142,258,000,000 cubic feet. All these reservoirs would hold only about *one-sixth* of the drainage of that year. This simple fact of itself should impress us with the magnitude of the undertaking to reduce this immense flow to uniformity, especially when we recollect that a single flood of a few days continuance will fill all these reservoirs.

Mr. Ellet shows, that a flood in March, 1841, the highest part of which was only 32 feet at Wheeling, discharged during *eleven* consecutive days, water enough to have more than filled all these reservoirs, and they would have been two-thirds full, or more, when this flood came. The flow in the month of December, 1847, would have filled these 29 reservoirs 1¼ times; and immediately after, on the top of these overflowing reservoirs, came the flood of January, 1848, which rose to 23 feet on the 3d, and to 26 feet on the 6th. How, under such irregular movements of the river floods, could we exert any useful control? And yet, what have we assumed to be done? We have erected dams of

50 feet height, placed continuously, beginning at Wheeling, and occupying the Ohio, the Allegheny, the Monongahela, and their principal branches; destroying the present navigation of all of them, substituting therefor a navigation composed of 50 feet dams, with some peculiar and novel arrangement of locks! We have assumed all this, and what do we accomplish? We secure a radical improvement of the Ohio River, but is it not at the cost of the destruction of every thing above the point where the improvement begins? Granted, then, that even at this cost the river may be improved, have we advanced one step towards regulating the flow of great floods? Let the accumulated facts herein arrayed, decide.

In another part of Mr. Ellet's paper, is this suggestion: "Yet as all the objections that can possibly be urged against the construction of high dams on these great rivers may be obviated, as already stated, by resorting to the smaller affluents, it will be the aim of the writer to make a *first demonstration* of his plan in localities remote from the leading channels of trade, and where there are no important private interests to be consulted."

If we discard dams of great height on the main rivers on account of difficulties that may be attendant upon their erection, and the anticipated injury to navigation interests above Pittsburgh, resort must, of course, be had to the upper waters, as above indicated. Suppose it possible to find sites for *five hundred* reservoirs, each having the capacity of the present Conemaugh reservoir, (466,000,000 cubic feet,) their united contents would be but 233,000,000,000 cubic feet, or a trifle over *one-fifth* of the quantity which flowed past Wheeling in 1847. And, had all these 500 reservoirs been in use, and entirely empty, on the 22d of January, 1840, they must have been filled to overflowing before the middle of February; and in the latter part of the same month, there was a flood of 36 feet height, to be regulated with every reservoir full! During that single short month, there flowed past Wheeling 307,046,000,000 cubic feet, or about *one-third* more than the aggregate capacity of these 500 reservoirs.

Again, in further exemplification of the particular point under discussion, if it were *possible* to locate reservoirs enough to contain the *entire drainage* of *a year*, such as 1845, when 555,482,000,000 cubic feet passed Wheeling. Another year, 1847, shows greatly more than *double* of that quantity passing the same point of observation; leaving 586,776,000,000 cubic feet unprovided for. Each one of these reservoirs would require the drainage of at least seventeen square miles. Now, let an attempt be made to locate 500 reservoirs, embracing localities each covering 17 square miles; or 250 reservoirs, each covering a locality of 34 square miles of drainage. In either case, practical difficulties will be encountered, greater than Mr. Ellet could have thought of at the time he wrote.

The writer, after investigating the records, with a view to the elucidation of this important feature of Mr. Ellet's plan of controlling great floods, is constrained to adopt the opinion, founded upon those records, that it cannot be practically carried out now, or at any future time.

And further, unless expense, damages, health, and navigation interests above Pittsburgh, be entirely disregarded, there are, it seems to the writer, two things proposed which are *not compatible with each other.* One, a system for maintaining the flow in the Ohio at all times up to 6 feet: the other, to prevent the flow from going materially above a uniform height. In one, we need only reservoirs enough to hold the quantity required to raise it from its low stage to 6 feet; in the other, vast river dams, or numerous reservoirs, (or both,) covering the best part of the country! The chief object in one case, is to *hold the water* back, and in the other to *let it go.* In one case we desire well filled reservoirs, in the other we must have them empty, or partially so, or they can be of no avail.

In the foregoing approximate estimates of quantities of water likely to be held by reservoirs, accuracy could not be expected. They are derived legitimately from such data, aided by experience, as to warrant the opinion that they are not likely to prove grossly erroneous; or sufficiently erroneous to alter the general conclusions. This inquiry is not conducted with the view of establishing any particular theory, but to bring the facts fairly before all. They show, at least, that reservoir sites suitable for such gigantic operations, are not so numerous, or so easily attainable, as the public may have been led to suppose. Reservoirs have become so common in connexion with canals and ordinary sluice navigation on minor rivers, such as the Lehigh, and the smaller tributaries of the Allegheny, that the transition to a much larger scale of operations, appears simple and easy. But what, in extent, are the supplies of water for canals, compared with the quantity contained in the flow of a river like the Ohio, at a regular six feet stage?

As a familiar example, take the old Erie Canal in New York, 365 *miles* long, with 40 feet water surface, 28 feet bottom width, and 4 feet depth. This prism would contain 262,099,920 cubic feet. A single day's supply through the dry season for the Ohio River, upon Mr. Ellet's theory, would fill that prism of 365 miles length, more than 4 *times.* A single one of the 500 smaller reservoirs already described, would fill it, and have 203,900,080 cubic feet to spare. This conveys a more tangible idea than the mere rehearsal of millions of cubic feet. But pursue the comparison a little further: allow that it would require on these 365 miles, 100 cubic feet per mile per minute, to keep up the loss from evaporation, soakage, and leakage, and that 100 boats per day should be passed through locks of 8 feet lift, with chambers 90 feet long and 15 feet wide: the total daily quantity would be 53,640,000 cubic feet. More than *twenty-one* times this quantity would be used in supplying the Ohio River, as proposed, for one day.

There is another practical consideration, already merely glanced at, which we dare not ignore—namely, the probable effect of such a system of reservoirs as that recommended by Mr. Ellet, upon the health of the country. B. Aycrigg, Esq., a Civil Engineer of superior attainments and judgment, formerly engaged in the service of the State of Pennsylvania, makes this remark in referring to this subject: "there may be water enough and places enough if we disregard expense, and the health in the vicinity of large areas, alternately covered with water and

exposed to the sun." Mr. Aycrigg is familiar with this region; he made the surveys for a continuous canal across the Allegheny mountains, and proved conclusively, that by means of reservoirs on the head waters of the Susquehanna and Allegheny, it could be supplied with water. He also had charge of the slackwater improvement on the Allegheny River, which was commenced by the same State, and afterwards abandoned from notions of policy which had no reference to the capabilities of the river. Mr. Aycrigg's opinion was decisively in favor of improving the Allegheny, to a certain extent, by slackwater, with dams of moderate height.

Whilst admitting that a *few* sites for reservoirs can be found not subject to serious objection on the score of health, the writer apprehends that an *extended system* of reservoirs, such as would seem to be necessary in bringing about any practical control of the Ohio River, might destroy the salubrity of large areas of country; and that it might happen, that neither any state nor the general government could sustain it. The writer is acquainted with two instances in the State of Ohio, one on the Sandy and Beaver Canal, and the other on the State Canal of Ohio, where reservoirs were forcibly torn down, and the waters let off by the populace, upon the plea, whether true or false, that they were injurious to the health of the people living around them. Nevertheless, he would not be misunderstood; his own opinion is, that it does not precisely follow, that the construction of a reservoir always endangers the health of the surrounding inhabitants. Something depends upon the character of the reservoir, and the manner of using it. But this point is entitled to grave consideration. We will next take up the subject of *low open dams.*

Low Dams with Open Sluice Ways.

Mr. Haupt, in his pamphlet published in 1855, entitled, "A Consideration of the Plans proposed for the Improvement of the Ohio River," introduces his own plan of low dams, as follows:—

"The case which has been considered is, that of an application of the ordinary slackwater principle, by means of high dams and locks. The objections to it appear to be numerous and formidable, but not insurmountable, and the importance to the general interests of the country of an uninterrupted navigation, would be sufficient to justify the expenditure if it were quadrupled. A system of low dams, with chutes of very moderate inclination, would be free from the delays of lockage; would oppose less obstruction to floods; would be less expensive in first cost, and less expensive in operation, and would throw but little impediment in the way of the descending coal and lumber trade."

This would be in the main true, if the plan did not require "artificial reservoirs," but as these necessarily constitute part of the plan, and as the erection of artificial reservoirs on the large scale required, is not yet decided to be easily practicable, this statement of conclusions must be received with some allowance for the present.

On the precise plan recommended by Mr. Haupt, there are other and more serious objections.

These low dams are to be without locks, to be open at one end for

200 feet in width left for a channel, with a mound in the river, extending from the end of each dam upward, lengthwise of each pool, forming, as it were, a *canal* on one side of the river. The plan, theoretically, is neatly elaborated ; but Mr. Haupt did not pursue it minutely through all its practical bearings. The difficulties inseparable from this peculiar arrangement, have been ably discussed in the paper of Mr. Morris, before mentioned. It would occupy much unnecessary space to repeat the whole of Mr. Morris' argument. The chief and vital objections are, that whilst one side of the river would thus be accommodated with a good ascending navigation for steamers, and a good descending navigation for rafts and arks, the other side of the river would be excluded from all participation, in consequence of the dam, and the mound along each pool, —the dam and mound together forming a *cul de sac*,—and in descending with steamers, even in the channel of such confined width, there would not be room to *round to* for landing. To reach any place above and near to a dam, on the opposite side from the channel, steamers would be forced to double the cape of the mound, whatever number of miles it might be. And secondly, the accumulation of sand and gravel, immediately opposite the mouths of the numerous tributaries pouring across this narrow canal, would obstruct and destroy the usefulness of the channel.

Although this plan requires artificial reservoirs, it would obviously need less aid from such supply, than Mr. Ellet's plan of keeping up the natural river.

A modification of the foregoing plan, dispensing with the mounds, and placing the channel at or near the middle of the stream, relieves it of both of the above serious objections. In this form, it is worthy of careful consideration.

Assuming that the present extreme low water depth on the bar at Wheeling is *one* foot, open dams high enough to raise the water 5 feet above that surface, would afford a six feet navigation, whenever there was water enough to keep the water in the open channel, as high as the level of the dam. A continuous succession of dams of 5 feet lift, having the pools connected with each other by channels or open sluiceways 200 feet wide, if well supplied with water, would make an admirable navigation. The length of the pools would vary according to the natural declivity of the river. On the most rapid portion, between Pittsburgh and Wheeling, they would average seven miles each, and on the more gentle part, below Cincinnati, about 15 miles each. Between Pittsburgh and Evansville, a distance of nearly 800 miles, where the aggregate fall is 379 feet, it would take 75 dams, with pools averaging 10½ miles in length.

In regard to the water supply, it may be safely assumed, that if provision be made for keeping up a flow of 6 feet depth through the sluiceways on that part of the river between Pittsburgh and Wheeling, where the most rapid descent occurs, it will be ample at all points on the river, particularly at the lower end, where the fall is less than half as great per mile.

Compared with the plan of feeding the unobstructed river, what proportion of water will be needed?

Mr. Ellet shows, that to bring the water up from the low stage of one foot to a six feet stage, would require a daily supply of 1,062,000,000 cubic feet. Now, assuming that with 6 feet depth in the open dam, in a channel 200 feet wide, the pools being full, the average velocity for the entire prism may be three miles per hour, the quantity passing every 24 hours would be 456,192,000 cubic feet. Deduct the quantity passing in the low water depth of one foot, 102,000,000 cubic feet, and it leaves 354,190,000 cubic feet per day to be provided, which is but one-third of the quantity necessary on Mr. Ellet's plan.

At first view, this plan of a succession of dams, may appear to be merely a reproduction of the old system of wing dams, used to concentrate water into contracted channels. If the plan were only an *occasional* dam at a ripple, it would be the same principle; but with a regular continuous succession of dams, equal in the aggregate height to the entire fall of the river, it is entirely different, inasmuch as they serve to equalize the fall along the whole stream, and when properly supplied with water, all ripples will be entirely lost sight of. The only object of these dams is to save the expenditure of water.

We find from Mr. Ellet's tables, that 3 feet depth on the bar at Wheeling represents a flow of 400,000,000 cubic feet per day, which corresponds nearly enough for present comparison, with the assumed flow for a 6 feet depth in the sluiceways of the dam.

There can be no doubt that these sluiceways in a river like the Ohio, falling only one foot or less per mile, (averaging under six inches,) formed as suggested, will be easily navigable at any stage of water by ascending steamers and descending craft of every description, not drawing more water than the depth of the channel. Indeed, this plan can be carried out on rivers of even greater declivity. Col. S. H. Long, so well and so favorably known in the public service, in his Report to the Secretary of War, of Sept. 1, 1855, makes some pertinent remarks on this very topic. He says, "Sluice navigation is believed to be practicable, ascending as well as descending, under the following limitations, viz: the width and depth of the channel being sufficient to admit the free passage of a steamer, the ascent may be effected in all cases where the acclivity does not exceed 3 feet per mile. The improvement of the rapids of the Mississippi is predicated on the feasibility of this postulate. * * * Letart's Falls on the Ohio and numerous other rapids above that point, are known to be navigable on terms less favorable than those above intimated. The Falls at Louisville have been ascended by steamers in medial stages of the river, when the acclivity was even greater than that above intimated."

Mr. Ellet, in his paper, remarks, "A descent of nearly 4 feet per mile is not incompatible with the existence of steamboat navigation, if the supply of water be well maintained; for a steamboat has ascended the Allegheny as far as Olean point; overcoming, in places, a slope of nearly 5 feet per mile."

Now, there is nothing so difficult as any of these, proposed in connexion with these low open dams. At the worst, there could scarcely be a velocity due to more than about two feet per mile fall, to overcome; less than is now daily encountered in the river at many of the ripples.

In Mr. Haupt's investigation of the flow of water, he bases his theory upon an isolated dam; which is different from a succession of dams, beginning at the upper end of the river where the fall is 12 inches per mile, and terminating at the lower end, with an average fall of less than 4 inches per mile. This succession, one dam backing the water against another, operates in two ways: in lessening the velocity of the flow through the sluiceways, and in greatly reducing the quantity of water necessary to keep up a six feet stage in the river. The difference is important, and the reason plain. In the case of an isolated dam, the water flowing freely through the sluiceways into the clear open river, meeting no obstruction, passes on with the velocity due to the declivity; whereas, in the case of a succession of dams, the same body of water which will fill the first pool, will also keep all the pools full.

The entire water of the pool will not move with the velocity due even to the middle portion, which is also retarded to a certain extent. It will present the aspect of a central current gliding through a larger body of comparatively still water. Thus, to express it roundly in figures, we may have a current two hundred feet in width passing at the rate of two miles an hour, whilst there may be 650 feet in width on each side, or 1300 feet in width, moving not over half a mile an hour. A portion, indeed, on the sides, may be back current or eddy water.

Again, if the same declivity of one foot per mile existed on the entire river, the same quantity of water would not quite fill the lower sluiceways of the series; but there are two constant causes obviating this, practically; one being the additional quantity of water entering the Ohio from its lower tributaries; the other its greatly decreased declivity.

These peculiarities in the natural regimen of the stream, may perhaps permit the use of wider sluiceways, and consequently shorter pieces of dams, as we descend the river. This seems to be a fair deduction. And furthermore, it is quite possible that the additional water required for the navigation on the upper portion of the Ohio, between Pittsburgh and Wheeling, on the plan of low open dams, may enable us to dispense with dams below Portsmouth. If not on that part of the river, at least below Louisville, where the declivity is but 2·8 inches per mile. It is expected that the government will soon finish the enlarged and improved canal at Louisville; in that event, on the latter supposition, the remaining works to be built would all be above the Falls.

It is obvious, that every portion of the river below the lower dam, wherever that might be located, would be *improved* by reason of the additional quantity of water obtained from the artificial reservoirs. This remark will of course apply with still more force to Mr. Ellet's plan, on account of the larger quantity needed at the upper end of the river.

Plan and Cost of a Low Open Dam.

An open dam raising the water only 5 feet from pool to pool, would be very simple, and easily constructed. Some of the dams would be founded on rock, but most of them, probably, on gravel. On gravel foundations, the dam should be composed of a timber crib filled with stone, and sheet-piled on the up stream side. On good rock bottom, a substantial common rubble wall laid in cement should be built. The

open space, 200 feet wide, might be covered with heavy paving, 18 inches thick, well clamped together, or, after the river had excavated the space several feet deep, it might be filled with a crib to the level of the bottom of the dam. A very cheap arrangement would ensure security at the shore ends of the dams, in all cases, as the water would not run over them until it was at nearly the same height from the back water of the next pool below. The ends of the dams adjoining the sluices, should be tapered from the height of the dam to the bottom of the sluice; presenting a channel about 225 feet wide at the top, and 175 feet at the bottom. Allowing the average width of the river at a 6 feet stage, to be even as great as 1800 feet, it would require but 1600 feet length of dam at each site, and for 400 feet total fall, 80 dams. My calculations give an estimated cost of about $35,000 for each, including two piers or beacons. The aggregate for the 80 dams is $2,800,000: adding 10 per cent. for the preliminary expenses, superintendence, &c., it makes a total of $3,080,000.

The effect of such low open dams upon the great floods of the Ohio, would be scarcely appreciable. It is not worth serious consideration, much less grave apprehension.

If it can be established beyond question, that this plan, as compared with Mr. Ellet's of keeping up the flow of the unobstructed river, may save two-thirds of the cost of the artificial reservoirs, that fact might lead to its adoption as an economical adjunct to the system of artificial reservoirs, in case they should be deemed preferable to locks and dams.

It is entitled to attention in another point of view, as it is quite evident that the low dams will increase the depth in the channels considerably, even without aid from reservoirs, though in the very lowest stages, they would be of no avail without such aid.

Mr. Haupt's analysis of the flow, founded on Mr. Ellet's paper, led him to the conclusion, that "whenever the quantity of water in the Ohio river would be sufficient to give a depth of 2 feet 8 inches on the bar at Wheeling, there would be sufficient to maintain *six feet* depth of water in an artificial channel 200 feet wide, flowing at the rate of 3·13 feet per second, or 2·1 miles per hour." This was based on its flow through the proposed river canal, running between the mound and the shore, with an assumed fall of one foot per mile. On the modified plan, the pools being once filled, very little more would be required for the flow through the sluiceways, than would have sufficed for the canal.

Should it appear on future examination, that a complete system of artificial reservoirs on Mr. Ellet's plan, would cost $20,000,000 or more, supposing it to be fairly practicable and allowable, it is pretty clear that the adoption of this modification would effect a great saving. Thus, assuming one-third of $20,000,000 or $6,666,666 as the cost for reservoirs on the modified plan, and adding the approximate estimate of the cost of the 80 dams, would give a total of $9,746,667, and a saving of $10,253,333. These are all, of course, but approximations.

But even this comparison does not present fully the two plans. There are other facts derived from the records of the depths of water kept at Wheeling, of sufficient interest to be here introduced, which have a fur-

ther bearing upon the question of adopting low open dams, as part of a reservoir system.

The following records of the different stages of water, contains some interesting facts, useful in the present investigation.

Records of Different Stages of Water Periods.

Lowest, or one foot stage.—The absolute lowest stage was in September, 1838, when for four days the water was but $\frac{7}{8}$ths of a foot. In the same year there were twelve days in September, and sixteen days in October, when it was at 1 foot. Total 32 days in 1838.

In 1839 it was not so low as 1 foot.

In 1840 it was at 1 foot in July for two days.

In 1841 it was at 1 foot in September for eleven days.

From 1842 to 1848 inclusive, it was not at 1 foot.

Thus, in eleven years it was as low as one foot for but forty-five days, or an average of four days per annum.

One and a half feet stage.—From 1838 to 1848, inclusive, it was never below $1\frac{1}{2}$ feet before July. In July, 1840, it was below $1\frac{1}{2}$ feet, but only for two days. During the eleven years, it was only eleven days (or one day per annum) below $1\frac{1}{2}$ feet as late as August. The whole number of days for the eleven years when it was below $1\frac{1}{2}$ feet, was 104, or an average of less than ten days per annum; and 66 days, or nearly two-thirds of it, occurred during the month of September.

In 1842, 43, 45, 46, 47, and 48, it was not below $1\frac{1}{2}$ feet. During 1838, for 45 successive days, it was below $1\frac{1}{2}$ feet.

Two feet stage.—During the eleven years it was not below 2 feet before July, or after November.

The total number of days when it was below 2 feet was 188; an average of 17 days per annum; and 62 of them, or about one-third, occurred in one year, 1838; and 55 of them in 1841. There were two years, 1842 and 1845, when it did not fall below 2 feet. The greatest number in one year was 62 days.

Two and three-fourths feet stage.—During the eleven years it was not below $2\frac{3}{4}$ feet before May, or after November.

The total number of days when it was below $2\frac{3}{4}$ feet, was 509, or an average of 44 days per annum. There were 99 of the total number in 1838, and 85 in 1841. The least number was 14 days in 1847.

Three feet stage.—During the eleven years it was not below three feet before May, and only for a single day (1838,) after November.

The total number of days when it was below 3 feet was 609, or an average of about $55\frac{1}{2}$ days per annum.

The greatest number was 109 days in 1841; next greatest 104 days in 1838; the least number was 15 days in 1847.

From the foregoing data it may be assumed for a *minimum*, that in each year the depth might be

As low as 1 foot,	.	30 days.
Between 1 and 1½ feet,	.	15 "
" 1½ and 2 "	.	17 "
" 2 and 2½ "	.	37 "
" 2½ and 3 "	.	10 "
		109 days in all, below 3 feet,

and that during the residue of the year, it will be at or above 3 feet, during which period it would need no artificial supply to maintain 6 feet depth in a 200 feet channel, on the low dam plan.

According to the tables, the natural flow for such season during the 109 days should be about as follows, 17,147,000,000 cubic feet.

The flow due to a 6 feet stage in the natural river for 109 days would be,	126,876,000,000	cubic feet.
From which deducting two-thirds would leave, . . .	42,292,000,000	"
And deducting the natural flow,	17,147,000,000	"
Leaves,	25,145,000,000	"

to be supplied by artificial reservoirs for carrying out the plan with the low dams. This quantity might be obtained by three large reservoirs on the Allegheny, and one on the Monongahela. Or, as equivalent, by 54 reservoirs of the capacity of the Conemaugh reservoir; not including or allowing for any loss from evaporation in passing from the sources of the tributaries to Pittsburgh.

From the records and calculations of Mr. Ellet, it will be seen, that the quantity required to keep up the 6 feet stage in the natural river during these 109 days, was, after deducting the actual natural flow, 109,729,000,000 cubic feet. This is within a trifling fraction of *four times* the quantity required for the low dam plan. The reason why it is so much more is, that the ratio of *deficiency* per day is so much greater.

But this is not all: there are still *other days*, when no artificial supply would be needed on the low dam plan, in which the deficiency for the natural river would be very considerable. Thus, in one year (1845), there were 139 days when the water was at or below 4 feet depth. There were 190 days in 1841, when the water was at or below 5 feet, and 207 days when it was below 6 feet. Taking 1838, when the whole number was,

Below 4 feet, .	.	133 days.
" 5 "	.	161 "
" 6 " .	.	164 "

In round numbers there were 24 days, river to be raised from 3 to 6 feet, 28 days from 4 to 6 feet, and 3 days from 5 to 6 feet; requiring 34,000,000,000 cubic feet to be added to 109,729,000,000 cubic feet, making an aggregate of 143,729,000,000 cubic feet of artificial supply. This would be nearly 5¾ times the quantity required on the plan of low dams. If the supply were dependent upon the small class reservoirs, it would require 308 reservoirs for the natural river. But if regulating reservoirs of large capacity should be deemed admissible on the main

rivers, the number of small reservoirs would of course be diminished on either plan proportionally.

I proceed to the consideration of the system of locks and dams as proposed for the Ohio River, which the writer finds he is compelled to treat more elaborately than he at first imagined would be necessary, in consequence of the number of objections—some apparently of much weight—which have been brought to bear upon it. The public, particularly those who feel a lively interest in, and desire a proper settlement of, this question, are entitled to something beyond a simple contradiction of allegations, or the expression of a mere opinion respecting these objections. It will be the endeavor of the writer to consider every real objection which has come to his knowledge by experience or otherwise. It will be found that the investigation of the objections will constitute the chief argument in favor of the system.

Locks and Dams.

Slackwater navigation, consisting of locks and dams, is nothing new; but latterly many arguments have been made and numerous objections raised against the introduction of a similar system on the Ohio River. Mr. Haupt remarks in his pamphlet, before quoted, "The opinion is generally entertained that the plan of improvement by the construction of a slackwater navigation, is the only one practicable."

It may be, that this plan having been in use many years in various parts of the country, is more generally *understood;* but public opinion, even in Pittsburgh, a city which suffers more than any other from the irregularites of the navigation, has long been divided respecting the *mode* of improvement that ought to be adopted.

Many yet believe, that the plan of operations carried on for a time by the general government, under the superintendence of Major Sanders, had it been continued, would have answered the purpose; though at the most, he only expected to secure 2½ feet in the channels in a dry season.

Experience has demonstrated, that there is not enough water to render the plan of loose stone wing dams and channel excavations successful, without large additional supplies of water from artificial reservoirs. Even a 2½ feet navigation for several months of the year on this plan could not be obtained without a very heavy expenditure; and such a navigation would not answer the present, much less the prospective demands of commerce; whilst every year it would be more disproportioned to these demands.

A modification of Mr. Haupt's plan combined with Mr. Ellet's plan of artificial reservoirs, would be far superior in every respect. It has been already described and discussed in preceding pages. Neither of these plans, namely, wing-dams, low dams and chutes, or artificial flow, as proposed by Mr. Ellet, can be perfected without the aid of reservoirs on a scale of considerable magnitude.

In regard to a system of locks and dams, or regular slackwater navigation on the Ohio, it is the firm conviction of the writer that no aid whatever is necessary from artificial reservoirs; and that future examinations will not only confirm this, but show, conclusively, that *at all*

times there will be a considerable surplus of water, which may be used for hydraulic purposes.

The opponents of locks and dams assert, that there is not sufficient water for a slackwater navigation, without the aid of artificial reservoirs. This may be called their *first objection.*

To support this objection, but one fact has been presented, and that fact unaccompanied with an explanation which would have destroyed the erroneous impression it conveyed. That fact is, that the Monongahela slackwater in dry seasons is short of water sometimes, and that the Company contemplate the erection of reservoirs on the head waters, in order to make up the deficiency.

Admitting this to be true, let us follow it up with another fact. "In 1838, at the period of the lowest water known in the Monongahela, Allegheny, and Ohio Rivers for a great many years, the flow of water in the Monongahela above Pittsburgh was found to be in round numbers only 12,000 cubic feet per minute, whilst the flow in the Allegheny, as gauged by Major (then Captain) Sanders, was found to be in round numbers, 150,000 cubic feet per minute, or over 12 times the flow of the Monongahela." These rivers form the Ohio, at Pittsburgh, and the two contained at that time 13½ times the quantity shown in the Monongahela. The remarkable difference in the volume of water supplied by these two streams in dry seasons, is so striking and well known that it ought not to have been ignored.*

Now dam No. 1 on the Monongahela just above Pittsburgh is about 1300 feet long and 15 feet high. No greater height is contemplated on the Ohio; and how much greater will be the length of the dams? None of the opponents of slackwater navigation, would willingly estimate the length of each dam, exclusive of the space occupied by the abutment and double locks, at over 1560 feet, or one-fifth more than that on the Monongahela. It has been proposed to fix the height from pool to pool at not exceeding 8 feet; whereas, in dry seasons, on the Monongahela, the lift is 9 feet or more. What are the elements for comparison? We have seen that in an *excessively* dry time, such as occurs once in ten years, —there was at the head of the Ohio at the very commencement of the proposed slackwater, over *thirteen* times as much water as there then was in the Monongahela, its smaller tributary, and upon which has been in operation ever since, the most successful lock and dam navigation in the Union. Were the dams on the Ohio to be of the same height, the leakage and evaporation should be the same per foot of length of dam; but the Ohio dams are to be one-ninth less in height from pool to pool, and one-fifth longer. Whilst there will be one-fifth more length, there will be one-ninth less pressure upon every leak. So that practically, the total difference of leakage must necessarily be very trifling.

The number of cubic feet passing at the head of the Ohio, as gauged during the remarkably dry season of 1838, was 233,080,000 cubic feet per 24 hours. The writer has no certain means of determining whether the *average* for the driest month was more or less than this measurement. But we have some testimony which may be regarded as corroborative,

*For some more recent measurements of the quantity of water in the Monogahela in a time of drought, see Appendix.

from the records at Wheeling, and Mr. Ellet's calculations. On page 53 of his pamphlet he remarks, "But though the Ohio River never ceases to send water to the ocean, it will be seen by reference to note D, in the Appendix, that during *the memorable drought of* 1838, there was a period of 120 consecutive days when the depth on the bar at Wheeling was less than 5 feet. The actual average daily discharge during these 120 days, computed by the formula given in this paper, was about 220,000,000 cubic feet." We have no means of deciding whether the influx from the tributaries between Wheeling and Pittsburgh was greater or less than the evaporation at that particular period. The coincidence in the quantities represented, the one by actual measurements at Pittsburgh, in 1838, and the other by intelligent deductions from measurements in 1849, connected with the recorded depths of 1838, at Wheeling, is rather remarkable than otherwise. The difference being less than six per cent. of the larger quantity. But to make sure, suppose we take an extreme case, and allow only *one-half* of the *smaller* quantity as the basis of a summer daily supply! Would the opponents of slackwater demand harder terms?

Allowing the locks to be 350 feet long and 60 feet wide in the chamber, with 8 feet lift, the quantity for each lockage would be 168,000 cubic feet. Estimating a lockage every five minutes during the 24 hours, there would be 288 lockages, using 48,384,000 cubic feet, which, deducted from the assumed minimum 110,000,000, would leave 61,616,000 cubic feet to supply the *leakage* and *evaporation* of the first pool. This is more than 3½ times the entire flow of the Monongahela as gauged in 1838. And it would be considerably more than the leakage, soakage, and evaporation on 365 miles of the Erie Canal, including 100 lockages per day.

No civil engineer could stand justified in constructing a dam not over 1600 feet long, with no more than 8 feet lift, that should leak to an extent approaching such a body of water. Such leakage would, in *eight days*, exhaust the Conemaugh reservoir, constructed to supply the deficiencies of 104 miles of canal—with numerous dams of *much greater height*, for a whole summer!

Mr. Ellet also remarks, that "During six consecutive years, from 1843 to 1848, inclusive, there was but one month, August, 1843, when the average flow on the Wheeling bar was (a trifle) less than two feet depth, and but two other months, August, 1845, and September, 1848, when the average flow was less than 3 feet." And according to his calculations, with two feet on the bar, the flow was 228,000,000 cubic feet per day, more than double of our assumed basis; and with 3 feet on the bar, 400,000,000 cubic feet, or over 3½ times the same.

With these *facts* for our guidance, is it unreasonable to expect that notwithstanding the Monongahela Company may be forced to resort to artificial aid, the slackwater on the Ohio will be well supplied without any such arrangement? Surely it cannot cost the Monongahela Company much to obtain the little additional water they may need merely for slackwater purposes, if, according to the calculations of Mr. Morris, and Mr. Ellet, it will cost so little to furnish a constant flow of *not less* than 5 feet depth for the broad current of the unobstructed Ohio, flowing

freely over its bed on a declivity of one foot per mile; and requiring 864,000,000 cubic feet per day, nearly *eight times* the quantity we have assumed to be *abundant* for the Ohio slackwater!

To controvert successfully, the opinion that there will always be an ample supply of water on the Ohio slackwater, should it ever be constructed, something more than a bare assertion to the contrary, with a mere reference to an inapplicable example, is looked for.

In the present state of the discussion, the writer thinks he will be sustained by the judgment of every candid examiner, in the opinion that this *first objection*, namely, want of water for the lock and dam system, has no reliable foundation. The question of water supply is a very important one, and we have endeavored in this case to put it to a severe test.

2. The *second objection* is, that the dams though only 8 feet high from pool to pool, will cause a vast increase in the elevation of the great floods, and consequently seriously damage property along the river, and destroy cities, mills, &c., &c. Much stress has been laid upon this objection: so much, indeed, that Mr. Morris has ventured to announce an opinion that it is fatal to the plan. Granting nothing in this stage of the question on this point, the great practical question to be decided is, will such dams create any material additional rise in times of *high freshets?*

Mr. Morris has, to some extent, investigated it, but he confines his observations mainly to the results of a particular case, on the Potomac River, and to one particular flood. He presents a profile of that river, showing the flood line of an 18 feet flood, and its effect with an 18 feet dam; from which it appears, that the increased rise at the upper end of the pool was 5 feet, and at the dam 9½ feet. The natural declivity of the stream being 2½ feet per mile, or two and a half times greater than the Upper Ohio, and *seven* times greater than the Lower Ohio. He then assumes, that "with similar dams on the Ohio, we must expect as a necessary consequence to augment the height of the river floods at least from *five* to *ten* feet; and with the impeded discharge these dams would have in a slackwater navigation from the others necessarily backing their waters against them, there is a strong probability that the augmentation of the floods *would be even greater.*"

Did Mr. Morris pursue this branch of the subject far enough? The writer has frequently been called upon to rebut the apprehensions of non-professional parties in regard to the effect of moderately high dams upon high freshets, but it is rare for an engineer to take this position. The difference in the natural fall of the stream immediately above the pool has an important bearing upon the effect of a sudden flood, such as he describes. It must have descended upon the pool much more rapidly on account of that greater declivity. But upon that same stream imagine a flood of three times the height of the dam, or 54 feet high above the natural river, would that have raised the water 5 to 10 feet higher? Yet this would be only equivalent to a 42 feet flood with the 14 feet dams of the Ohio; and what would be the *additional rise* in such a flood? Something depends upon the suddenness or slowness of the rise. No unbending formula, can by any possibility be made prac-

tically applicable to the case ; but from experience, sustained by some calculations, a tolerably near approximation to the common and probable result may be had. We must keep the fact in mind, that in such heavy floods the entire body of water in the pool is set in rapid motion, however sluggish it may have been just before, and that the *mass* goes along with the sweeping current, whose velocity is *greatly increased* as it passes the dam, until the entire prism of water has assumed nearly a regular plane along the valley, at comparatively little greater elevation than if the dams had not been there.

On a 42 feet flood on the Ohio at Wheeling, an increase of one foot to the top surface, would add a thousand millions of cubic feet per day to the quantity flowing. The average depth of the proposed pools at low water is to be 10 feet. The total daily flow that would be due to that depth along the unobstructed river, would be only 2,754,000,000 cubic feet, or but 2¾ times the flow due to one foot of depth on top of the flood, and this lower prism of water would be flowing onward with more than *double the velocity* due to its original height of ten feet, and with still greater velocity as it passed the dam. The practical operation is such, that could some Titan wrench the dam entirely from its foundation, and hurl it out of sight, the apparent effect upon the flow of water in the river, would be little more than to equalize the velocity, without varying the surface perceptibly. If we should apply to this case, as analogous, the experience obtained on the Potomac, with an 18 feet flood on an 18 feet dam, we should commit a serious error. If we add "5 to 10 feet," or even 5 feet, to the height of the 42 feet flood on the Ohio, it will be found that the quantity of water that would be required to sustain the flowing prism, would be much greater than the quantity contained in the natural flood added to the artificial portion contained in the pools before the flood came: that it is in the nature of things, under any ordinary circumstances, an impossibility. But waiving for the present all theory, let us turn to further results of experience.

Experience on Rivers with Dams.

The writer has had practical experience in constructing and witnessing the operation of a great number of dams, through a period of thirty years, on the Lehigh, the Schuylkill, the Swatara, the Susquehanna, and the Juniata, east of the Allegheny Mountains; and on the Monongahela, Big Beaver, Little Beaver, French Creek, Kiskiminetas, Shenango, and Conneaut, west of the Mountains. There are other rivers, such as the Youghiougheny, Muskingum, Kentucky, Green, Licking, Miami, White Water, Des Moines, &c., which have been wholly or partially improved by means of dams, concerning which he has a general knowledge.

The facts, derived from actual observation and from reliable testimony, tend to prove, that those persons living along the streams who were once apprehensive of the effects of the floods, have been agreeably disappointed in the actual results.

As before remarked, no single rule can be made practically applicable upon all these different rivers. The experience of the writer will

warrant him, however, in suggesting some general limits as to the probable effects on the Ohio River of dams of the height proposed, in connexion with freshets, as they ordinarily occur, as follows: that where the natural freshet should be twice the height of the dams, or 28 feet, the average *additional* rise along the pools of the 14 feet dams, will not exceed one-fifth of the height of the dam; and that where the natural freshet should be three times the height of the dam, or 42 feet, the additional rise along the pool will not exceed one-tenth the height of the dam; and that where the natural freshet should be four times the height of the dam, or 56 feet, the additional rise along the pool will not exceed one-twentieth the height of the dam. The flood of 1832, which rose 62 feet at Cincinnati, was nearly four and a half times the height of the proposed dams; and had they been in existence at the time, the difference in the height of the water could scarcely have been perceived, as *theory* will in part show, and as experience in part teaches.

The very considerable variations in the width of the Ohio at different points, particularly with reference to high floods, and the variable effects of the side floods, from the larger tributaries, dependent largely upon the relative periods of attaining their greatest force, and upon the particular direction their cross currents may take when entering the main river, have far more influence upon the heights of great floods than these dams can have.

Thus, at one time, the Allegheny will send a back current many miles up the Monongahela, over the dam, and at another time, the Monongahela flood will rush for miles up the Allegheny. The Big Beaver, the Licking, the Kanhawa, or the Cumberland, may be in flood, when there is little or no rise in the Ohio proper; or the Upper Ohio may be in flood when all of the streams just named are quite low. The variations in the heights of floods on different parts of the river from these causes, will be greater than the variations or changes caused by the introduction of the dams. On the Monongahela, where 15 feet dams have been in use many years, and where the larger floods previous to their erection may have been about 30 feet, experience does not show any material *additional* rise. In the spring of 1852, these works were subjected to the severest test from two heavy floods which "occurred in the month of April—the first from the 3d to the 10th, and the second from the 17th to the 24th, which entirely submerged the improvement, and suspended the receipts. These freshets were both greater than any that have preceded them since the memorable flood of 1832, one of them exceeding that, or any other known upon the Monongahela."

Mr. Morris says, "a remarkable point in the experience of the Monongahela navigation, verifies our freshet profile (fig. 5), in a satisfactory manner, and shows its applicability to those rivers, it is this, that whenever the depth of a freshet on the comb of the Monongahela dams is equal to their lift (8 feet), they are always safely passed by steamboats without using the locks, the dams being completely drowned out. Now our profile (fig. 5), shows that about the point near the head of the pool, where another dam would have been placed to continue a

slackwater navigation, the depth from the freshet line to the low water level of the pool is 19 feet, or just double the depth on the comb." He is still using the Potomac River as an exemplification. Although what he states respecting the depth of water, and passing of steamboats over the Monongahela dams is correct, its applicability in the particular comparison made, is certainly doubtful. It shows, at all events, that 8 feet *on* the dam, passes as much water as 26 feet depth just below the dam. Still it proves but little when applied to greater floods. Mr. Morris, pursuing the same train of reasoning, founded on the test on the Potomac, as related, continues, "Hence, we may probably generalize thus far at least, *that with a series of equal dams of about ten feet lift succeeding each other in a slackwater navigation, upon a river of uniform section, the freshet depth on the comb of one is just half the backwater raise above that level at the foot of the next;* consequently, whenever the freshet depths of water upon the combs equals the low water lift of the dams, the top water surface of such freshet will present a continuous inclination, or the dams will be drowned out and passable by boats." This appears to have been partially the case on the Potomac in the instance cited, where the fall of the river above the pool is 2½ feet per mile, the dam 18 feet high, and with an 18 feet flood. It is remarkable in the profile showing the surface line of that flood, that it is represented as being actually one foot *higher* half a mile below the upper end of the pool than it was a mile higher up the stream. This may have arisen in part from some local obstacle, and in part may be attributed to the great declivity of the river, causing the freshet to strike the still water at the pool with great velocity, creating a partial reaction. Such would not be the case on the Ohio River, where the average fall is less than 6 inches per mile.

The inclination of the river must be taken into account in generalizing, when we come to consider the effect of a given *quantity* of water passing in a freshet. Thus, to take extreme cases for an illustration, we have two rivers, one falling 1 foot per mile, the other 10 feet per mile; each to be 100 miles long, with dams of 10 feet lift. The first would take ten dams and pools each ten miles in length; the other would have one hundred dams with pools each but one mile in length. Mr. Ellet has very beautifully exemplified that "a flood is but a lengthened wave," and this wave would present very different aspects in passing along these two different rivers, in the velocity of its movement, and in the relative height it would take above the pools. A like quantity of water would of course cause a higher rise in the natural stream of gentler declivity; but the question is, how would freshets of *equal height*, for instance, 20 feet over the natural bed, be affected by the dams on these dissimilar rivers? The "lengthened wave," on the gentler stream, would stretch forward, gradually spreading out along each successive pool; whilst in the other, it would be abruptly checked in its impetuous motion ten times as often in the same distance; so that whilst a flood of 20 feet in the gentler stream might not cause an additional rise of more than about 2 feet or less, a flood of 20 feet on the rapid stream might cause an additional rise of 4 feet or more, over each successive short pool. These figures are merely used to verify the reasoning.

Retaining these dissimilar streams still in the mind, how would the comparison stand taking an equal *quantity* of water, and comparing its effect on the two? The quantity that would make a natural flow of 20 feet on the gentler stream, would not be more than 7 feet along the rapid stream—both in their natural condition without dams. On the gentler stream, in passing the dams, we should have about 12 feet depth over them, and on the rapid stream, perhaps about 4 feet depth over the combs. But mark, in the case of the gentler stream, the dams as a system, have caused a rise of only two feet above the natural height of the water immediately below each dam, whilst in the case of the rapid stream, the dams, as a system, have caused a rise of 7 feet immediately below each dam. A simple diagram, which almost any one can make, will render this clear.

There are facts connected with freshets in the Schuylkill River at the Fairmount dam, which have a direct bearing. The precise height of the dam is not recollected, but the writer believes it is about 12 feet above low tide, and about six feet above high tide. The river, at the distance of a third of a mile, perhaps, below the dam, is contracted and absolutely confined by bridge abutments to a width of about 350 feet, which operates to some extent in swelling the *high* floods above the bridge, and on the dam. The effect of sudden floods is dependent in part upon the state of the tide. With these premises before us, let us see how floods have operated there?

In January, 1839, a freshet rose to $10\frac{1}{6}$ feet on the dam, and below the dam to 13 feet above ordinary high tide, or 19 feet above low tide.

In July, 1850, the water was 8 feet on the dam, and $9\frac{1}{4}$ feet above ordinary high tide, or $15\frac{1}{4}$ above low tide.

In September, 1850, it was $10\frac{11}{12}$ feet on the dam, and $13\frac{1}{2}$ feet above ordinary high tide, or $19\frac{1}{2}$ feet above low tide.

We can, in this record, trace the very principle the writer desires to inculcate; although on account of the tidal effect, and the bridge abutments mentioned, the whole rise may have been somewhat greater.

Thus, in the smaller freshet of July, 1850, with 8 feet on the dam, it gave $15\frac{1}{4}$ feet at low tide; so that at most, the flood in the natural stream below was not quite double of the depth on the dam. The *increase* appearing to have been $4\frac{3}{4}$ feet, or not quite 40 per cent. of the height of the dam above low tide, with a flood only one and a third times the height of the dam to low tide.

In the freshet of January, 1839, with $10\frac{1}{6}$ feet on the dam, it gave 19 feet above low tide. The *increase* appearing to have been but $3\frac{1}{6}$ feet, or a fraction over one-fourth of the height of the dam, with a flood only one and seven-twelfths times the height of the dam at low tide.

In the freshet of September, 1850, with $10\frac{11}{12}$ feet on the dam, it gave $19\frac{1}{2}$ feet above low tide. The *increase* appearing to have been $3\frac{5}{12}$ feet, or a trifle more, in proportion, than in the January flood of 1839, with a flood only one and five-eighths times the height of the dam to low tide.

It will be observed, that whilst with a flood one and a third times the height of the dam, the *increase* of rise caused by the dam, &c., was

forty per cent. of the height of the dam; with another flood, one and seven-twelfths times the height of the dam, said *increase* was but *twenty-six* per cent. Thus, although the larger flood was 3¾ feet higher, it only raised the water 2⅛ feet higher; showing how rapidly the relative effect of the dam diminishes with the augmentation of the floods. Let the same principle be applied to floods of double the height here recorded, and the per centage of the *increase* in question will fall accordingly. It will appear that the assumption of one-fifth of the height of the dam is a very liberal allowance to make for the *increase* on a 28 feet flood on the Ohio River, with dams of 14 feet height; and that one-tenth of said height is a liberal allowance for a 42 feet flood.

The practical conclusion, based on experience, and on such reasoning as the nature of the problem has induced in the mind of the writer, is, that the increase of rise and the consequent increase of damage likely to be caused by dams in the Ohio, with vertical heights from pool to pool, not exceeding 8 feet, when placed in comparison with the magnitude of the interests sought to be benefited, will be deemed insignificant.

The reader will readily perceive that this has no reference to another class of damages also referred to—that is, the actual constant *overflowing* of low bottom land, and of a few mill privileges near the mouths of some of the tributaries. Surveys, or the records of old surveys, will show the extent of this character of damages; but judging in part from the results along the Monongahela, it cannot be a very heavy item.

The writer frankly admits that it is a legitimate objection to the system of locks and dams, that *any* increase of rise should be caused at any time in consequence of the dams, but he feels quite confident that undue importance has been attached to it for want of a full investigation.*

3. *The third objection* is, that the "dams will cause the river to be much more frequently and longer obstructed by ice, and will render ice freshets both more frequent and more dangerous."

In considering this objection we must keep in mind the fact, that in comparatively low water, such as is common through the winter, the Ohio River is already but a collection of pools and ripples; the latter being in fact nothing more than flat, sloping, natural dams. When these pools shall be made ten feet deeper by the erection of artificial dams, they will be less liable to freeze, and the ice upon them will be thinner on account of the increased depth in the pools. This is an undeniable natural truth. Again, in low water and freezing weather, the steamers are now forced to cease running *sooner* than they will be after the dams are built, thus leaving the river in undisturbed possession of winter's icy fetters; whereas, with the slackwater in constant operation, there will be no *low water*, and steamers will never cease running until *very severe* freezing should set in.

But without pursuing the theory any further at present, let us look at a practical statement introduced by Mr. Haupt on page 21 of his pamphlet.

* For further corroboration of the general theory, and of the practical effect of dams, see Appendix.

He says, "The following statement of the detentions caused by ice on the Monongahela, has been furnished by J. K. Moorhead, Esq., and embraces a period of 10 years, from 1845 to 1854 inclusive.

1845,	Feb. 7 to Feb. 14, inclusive,	8	days.
"	Dec. 7 to Dec. 31, "	25	"
1846,	Jan. 1 to Feb. 1, "	32	"
1847,	Dec. 11 to Dec. 16, "	6	"
1849,	Jan. 10 to Jan. 18, "	9	"
"	Feb. 15 to Feb. 26, "	12	"
1851,	Feb. 1 to Feb. 2, "	2	"
"	Dec. 19 to Dec. 31, "	15	"
1852,	Jan. 12 to Jan. 31, "	20	"
1853,	Jan. 26 to Feb. 1, "	7	"
"	Dec. 28 to Jan. 15, 1854,	19	"
	Total number of days,	155	"

or an average of 15½ days in each year."

Mr. Moorhead also states that, "*the Ohio River has been obstructed by ice nearly the same length of time.*"

Now if the total time per year, namely, 15½ days, were *all* to be considered chargeable to the slackwater navigation, it would not be a very heavy item. Every one can judge how much weight he would allow to the third objection—on the score of the ice question, so far as the period of stopping navigation is concerned.

On the second branch of the objection, that the "ice freshets will be more frequent and more dangerous," we think, on considering the facts, that precisely the reverse will be the case; namely, that they will be *less frequent*, because an equal quantity of water from rains, snows, or thaws, flowing into the deeper and larger pools, would not so readily put the ice in motion, and because the ice being thinner in the first instance, would necessarily be weaker and less dangerous before it commenced moving, and when it did move, it would be immediately broken to pieces at the dam, and go forward in less formidable masses, until it reached its melting or sinking point in the river. Mr. Lothrop, for many years chief engineer on the Monongahela Slackwater, has assured the writer, that such has been the experience there.

The damage from ice, with an experience of 18 years, has not been serious. Most of the Ohio River is farther south than the Monongahela by several degrees; the most northerly point of the Ohio is only about one-fourth of a degree north of the mouth of the Monongahela. And if a *few* boats on the Monongahela have been able to maintain a perennial navigation lacking but 15½ days per year, will not a much greater number on the Ohio approach that desirable result still more nearly? Theory and experience unite in favor of the assumption that the ice will be less troublesome in every respect after the completion of the slackwater.

4. *The fourth objection* is, that "it will injure the lumber trade and coal business." This is a plain practical objection, which is to be met in a plain practical manner. It is undoubtedly one of great moment. It has been answered in newspaper articles, &c., at different times through a number of years. Mr. Morris, when suggesting in the *Appendix* to his paper, that the writer had committed an oversight in re-

gard to *sluiceways* in connexion with arks, was not perhaps aware of the fact, that the sluiceways proposed in the dams were designed almost wholly for the accommodation of the rafts and arks descending the Allegheny River, which can only run when there is some *rise* in that river, at which time it is presumed they can pass the sluiceways of the dams safely. It was no part of the design, so far as the writer's knowledge extends, to promise a navigation at the sluiceways when there was no corresponding natural navigation on the Allegheny River. The idea was, and is, simply to make such provision for the descending craft of the Allegheny River as would enable them, when they could run to Pittsburgh, to continue on if they so desired, without being compelled to use the locks.

With the proposed extension of the slackwater navigation below Pittsburgh through the whole length of the Ohio River, the idea of using common *arks* for the coal business was exploded, and a system of barges recommended as the proper economical substitute. The day is rapidly approaching, when the scarcity of the right kind of timber will of itself render this step necessary. Arks will be discarded on the Ohio, just as they were on the Lehigh, when the canal was substituted for the descending sluice navigation first constructed. With a good reliable slackwater navigation, the coal business will be augmented to a vast extent, and carried on with an immense saving over the present precarious, costly, and annoying arrangement—if arrangement it can be called. But it is not intended to enter into a detailed investigation of the coal business at this point in the argument. It merely comes up incidentally in the explanation of a misunderstanding in relation to the character and object of the *sluiceway* spoken of as part of the lock and dam system. And yet Mr. Morris is in part correct in his conclusion, when he says, in the *Appendix* alluded to, "for if these sluiceways or chutes are so arranged as to admit the safe passage of those burdensome but frail boxes of pine lumber, called 'coal arks,' which draw six feet water, it is clear that they must also answer for the transit of the stronger steamboat, which never draws so much"—true, when there is six feet clear depth on the sluiceway, it is expected that steamers may and will pass up and down without using the locks. Mr. Morris proceeds—"In this shape, this plan, in fact, becomes the plan of Mr. Haupt, that of 'low dams and chutes.'" Whereas, when understood, the two things are quite different; Mr. Haupt's plan being designed for low water, with an actual opening through the dam, whilst the sluiceway or chute referred to by the writer, is a mere prolongation or flattening of a portion of the dam up and down stream, not calculated for low water use, the pools being always kept full.

With the slackwater completed between Pittsburgh and the Mississippi River, the entire business would be revolutionized within a few years, from choice on the part of the lumbermen and coal dealers. A large proportion of the lumber, and all the coal, would be conveyed in barges to the Lower Ohio, and thence up and down the Mississippi. Still it is no part of the plan to force trade of any kind. Coal boats, even now, drawing six feet water, cannot with prudence be started from

Pittsburgh with less than 10 feet water in the channels, and with such a body of water, the chutes can be so arranged as to permit their safe passage.

Although dams not exceeding 8 feet height from pool to pool may be thus arranged, the writer is at a loss to know how such an arrangement can be made in dams fifty to one hundred feet high, as proposed by Mr. Ellet and Mr. Morris for the Allegheny River above Pittsburgh, notwithstanding Mr. Morris has intimated that "it is not difficult." Another argument of Mr. Morris, fortunately applies below as well as above Pittsburgh. He says, "that the lumber will only be passed down at stated periods, forms no objection: since with unobstructed streams, it is only *occasionally*, and at very *uncertain* times, that it can now be run at all."

To the mind of the writer it appears clear, that whatever objection there may be—on account of the descending navigation interests—to the improvement of the Ohio River by means of low dams, will be much more forcible in connexion with the high dams suggested as part of Mr. Ellet's plan, notwithstanding the latter are to be placed above Pittsburgh.

5. *The fifth objection* is, "the cost, cost of maintenance and tolls." These may naturally be classed under one head. The leading idea intended to be disseminated under this fifth objection, is, that on Mr. Ellet's reservoir plan the first cost will be less, the maintenance less, and the tolls nothing.

Having advocated the improvement of the Ohio River as a national work, and presuming that it may be thus effected directly or indirectly, the writer cannot perceive the point of difference so far as *tolls* are concerned. If the government expends $20,000,000, in constructing, repairing, and managing artificial reservoirs for making an artificial river, and is not to charge citizens using the same any tolls therefor, why should the same government expending ten or twelve millions in constructing a slackwater improvement charge any tolls for the use thereof? Is there any *principle* in one case not involved in the other? Whether it will cost more to maintain and manage the slackwater than it will to maintain and manage reservoirs, is a point yet to be determined. But if it should be proved likely to cost more, that could only affect the *rate* of tolls, not the principle of charging tolls.

The first cost of a slackwater has been variously estimated by its friends at six to twelve millions of dollars; by its opponents at ten to twenty-five millions. Some have set down ten millions as necessary for "auxiliary reservoirs," for slackwater purposes. But this last item must be regarded as very extravagant in view of the claim, that it would cost less than two millions to furnish water enough to keep up the flow on the entire natural river to a five feet stage, all the year round, as estimated by Mr. Ellet, and approved by Mr. Morris. Surely, it ought to cost much *less* than two millions for any possible imaginary need for slackwater use! Why a five feet flow, according to the calculations, affords 864,000,000 cubic feet in 24 hours. Now a lockfull, of the largest size, as already shown, is but 182,000 cubic feet, and allowing a lockage every 2½ minutes, or 24 lockages per hour, or 576 per day,

it would be but 104,832,000; leaving 759,168,000 cubic feet, or a flow equal to more than 4 feet depth over the Wheeling bar, for the evaporation and to leak through the dam—a most extravagant assumption, certainly.

Does not this show to the candid inquirer, that the expression "ten millions of dollars for auxiliary reservoirs," is made entirely at random? This incongruity is glanced at without for a moment admitting that there can ever be any necessity for reservoirs of any kind for the lock and dam navigation. In continuation of the thought in connexion with the lockages just assumed, look at the aggregate result it would give! Allowing an average of but 500 tons to each lockage, it would be 288,000 tons per day, and for 340 days per annum, *one hundred and twenty-nine millions of tons*; an amount perhaps *ten times* greater than may be expected for some years to come.

Under the head of this fifth objection, relating to the "cost, maintenance, and tolls," it may be proper to enter somewhat into detail. Is it very difficult to make a reliable estimate of what the slackwater improvement ought to cost? As an engineer, the writer is constrained to answer that it is one of the simplest problems that could be presented to those members of the profession who have had experience in constructing river locks and dams. Except as to the damages that may be caused by actual overflow from backwater, the items are such as admit of an easy solution. Mr. Morris, including ten millions added for auxiliary reservoirs, adopting Mr. Ellet's random estimate of twenty-five millions, assumes thirty-five millions as the probable cost, and then proceeds to say, "even this great sum will not appear large to those civil engineers who reflect that such works as would be necessary to control this mighty river—constructed upon the dangerous gravel bottom which forms its usual bed—have never yet been executed in any country."

To warrant this there must have been something contemplated which has never entered into the calculations of the writer. He has only thought of carrying out very much such plans as he has carried out successfully before. The Monongahela River, in its natural state, as surveyed in 1838, was too nearly like the Ohio River in its present condition, to render such language applicable to one without being almost equally applicable to the other. The average fall in the Monongahela below Brownsville, was seven inches per mile; the fall in the Ohio between Pittsburgh and Wheeling, is about ten inches per mile, and between Wheeling and Cincinnati, 6¾ inches per mile. There is not difference enough in the natural declivity to base any strong argument upon; and on an average, what difference there is, is in favor of the Ohio River. Secondly, the bed of the Ohio is as much like that of the Monongahela in its characteristics, as any similar distance on the Ohio is like any other part of itself. On each river rock bottoms sometimes occur, but generally the foundations will be gravel, not *sand* in any case—the gravel being of precisely similar general character. Thirdly, the very high floods on the Monongahela had risen to about the same elevation as those on the Upper Ohio—over 30 feet above low water. True, at Wheeling the Ohio has risen 45 feet, and at Cincinnati 63 feet

above low water. It is yet to be decided whether this will operate for or against the system of locks and dams, as proposed. If our proposition was, as figuratively expressed, to "bridle" the river, the fact that the Ohio River rises higher than the Monongahela, might have an important bearing; but as no such thing was attempted on the Monongahela, it is not proposed on the Ohio. On the contrary, instead of "bridling," every arrangement consistent with the convenient management of the locks was made, to afford the floods a clear sweep. The lock-walls were designed to be only of such height that when the navigation over the dams should be safe, they would be submerged, and the locks for the time being would not be used. What essential difference will it make, whether they be submerged with 20, or 10, or 5 feet depth of water? Fourthly, the dams on the Monongahela below Brownsville, are 15 feet high above the bed of the river, and above Brownsville 19 feet. Those on the Ohio are not to exceed 14 feet. The longest dam on the Monongahela is 1300 feet. After deducting the space occupied by the double locks, it is thought that those on the Ohio will not average over one-fifth more or 1560 feet. Fifthly, the large locks on the Monongahela are 250 by 55 feet; it is proposed that the locks on the Ohio shall not exceed 350 by 65 feet. The difference is mainly a question of cost, involving no peculiar engineering problem. Locks as large as the largest yet proposed for the Ohio, have been built on the ship canal of Sault St. Marie, below Lake Superior.

What then is it that is to be encountered on the Ohio that has not already been met and overcome by American engineers? The principal difference between the regimen of the Monongahela and Ohio Rivers, arises from the greater height of the floods on the middle and lower portions of the Ohio. The locks will be more frequently and longer submerged. On the other hand, the dams being one foot less in height, the river over them will become boatable a little sooner than on the Monongahela, and will continue so for longer periods. There are some advantages as well as disadvantages in having the locks submerged. So far as the dams alone are concerned, the lower they are the better; but in connexion with locks we must take care not to increase the number unnecessarily. As low water periods cover about one-half the boating season, it will probably be found that the height already suggested, 8 feet from pool to pool, is convenient and proper.

We will then assume that we have to estimate the cost of a double lock 350 by 65 feet chamber, with 8 feet lift, and a dam 14 feet high and 1560 feet long. We assume substantial rubble stone work for the lock walls and abutments, and timber cribs filled with stone for the dam.

Estimated cost of one Dam and two Locks, including chute in Dam.

Foundation excavations, 4000 cubic yards at 75 cents,	$ 3000·00
" " 5000 " 25 "	1250·00
Abutment masonry, 1500 " $6,	9000·00
Crib timber, 7500 feet lineal, at 15 cents, . .	11,250·00
Upper covering, 170,000 feet B. M., at $20, . .	3400·00
Lower " 40,000 feet lineal, at 15 cents, .	6000·00
Sheet-piling, 50,000 feet B. M., at $20, . .	1000·00
Iron, bolts, spikes, &c., 75,000 lbs. at 10 cents, .	7500·00
Amount carried forward,	$42,400·00

Amount brought forward,	$42,400·00
Stone filling, 24,000 cubic yards, at 80 cents, . .	19,200·00
Excavation of foundations, 7000 cubic yards, at 75 cents,	5250·00
" " 4000 " 25 " .	1000·00
Feet lineal of timber, 3600 " 15 "	5400·00
" B. M. plank, 264,000, at $20, . . .	5280·00
" " sheet-piling, 15,000, at $20, . .	300·00
Pounds of iron, bolts, &c., 22,000, at 10 cents, . .	2200·00
Cubic yards of lock-walls and head-wall, 10,200, at $7,	71,400·00
Gates and fixtures, ...	20,000·00
Lock house, ...	1000·00
Chute in dam, ...	12,000·00
	$185,430·00
Add for contingencies and engineering, 10 per cent.,	18,543,00
	$203,973·00

Allowing that the entire length of the Ohio River should be embraced, requiring 50 dams, it would make a total of $10,198,650.

In round numbers, ten millions of dollars, not including damages that might be caused by overflow; which, however, is not likely to be a very heavy item. We may reason, *a priori*, from the fact that the Ohio River is *at all times* subject to floods rising 40, 50, and even 60 feet above the ordinary stage, that there cannot be a very great amount of property exposed to injury from an overflow which averages but ten feet, and no where exceeds fourteen. Experience on the Monongahela River confirms this view. The damages alluded to will not probably constitute a large or controllihg item. It is true that a careful examination will be required to determine accurately what it may amount to, but we may apply some judgment respecting it in advance. In the opinion of the writer, a total cost of eleven millions of dollars will cover the entire improvement including damages.

Cost of Maintenance per annum.

1 general superintendent, . .	$ 5000·00
3 assistants, at $1500, . . .	4500·00
9 foremen, " 600, . .	5400·00
90 hands, " 400, . . .	36,000·00
100 lock-tenders, 300, . .	30,000·00
3 steam tows, interest rent, . .	15,000·00
6 flats, " " . .	1200·00
Materials, ...	10,000·00
Total,	$ 107,100·00

Being about one per cent. on the original cost.

And even if the government should provide for 6 per cent. per annum in addition on the gross cost, and charge all to the improvement, the total per anuum would be but $767,100.

What rates of tolls would it be necessary on this assumption to charge to cover all? If we take the aggregate *value of the business* to be accommodated on a complete navigation at $400,000,000, it would be less than two-tenths of one per cent.—less than two mills on the dollar of value!

And what would be the saving to merchants, manufacturers, farmers, and all consumers? It would be many millions of dollars in insurance.

In absolute saving from destruction of thousands not insured, including an immense amount of coal now annually lost. In increase of profits from increase of business with less invested capital. In saving of interest on great quantities of produce and manufactures which now lie worse than idle for months. In the certain and general increase of all descriptions of business along the Ohio River valley which must follow the completion of such a reliable navigation.

The annual saving in insurance alone, will go far towards covering the entire aggregate.

Next, in regard to the coal trade: it has been stated by intelligent gentlemen familiar with the coal shipping business of Pittsburgh, that the annual loss in various ways, is about 20 per cent. of all that starts to go down the river. On the limited amount of one million tons, this would show an actual loss of 200,000 tons, which at an average of $4 per ton for the value down the river, would be $800·000; which is more than the whole toll required to cover interest on cost and maintenance of the improvement. But with such an improved river we shall have *three millions* of tons almost immediately upon its opening—thus presenting an annual saving fairly to be considered of $2,400,000 on the single article of coal. Nor is this all. There is now a heavy expense attending the coal business, which would be entirely cut off, namely, watching and bailing coal arks while waiting days, weeks, months, sometimes almost half a year, for a rise in the Ohio to take them out. The great amount of dead capital which must now be invested in consequence of this mode of doing the business is a serious clog upon its progress.

It is well known that some of the finest coal fields in the world are to be found between Wheeling and Pittsburgh, and along the tributaries above, and that the cities below on the Ohio and Mississippi consume large quantities from that region, and would consume *much more* could the supply be made certain and regular, with a reasonable regular price instead of a fluctuating scale varying from 12 to 40 cents per bushel. There has not yet been discovered along the Lower Ohio or Mississippi Rivers, any coal comparable to the Pittsburgh seam for gas purposes. Applying the calculation to only one and a half millions of tons of coal per annum, which is equal to 42 millions of bushels, a charge of one cent on the thousand miles of the Ohio River would be $410,000—a charge that would be saved to the coal interests several times over any year. And this is but one branch of the great aggregate trade upon which this merely nominal tax would be distributed! It is not too much to assume that the entire cost of carriage of the coal on the improved navigation will be less than the present annual aggregate losses and extra charges. But this is not the place to enter into further detail in relation to this important question. In due time its investigation will doubtless be fully made.

The receipts on the 55 miles of Monongahela navigation in 1852, were $62·666, or an average of about $1340 per mile. The same business at similar low rates per mile on 1000 miles of the Ohio improvement would be $1,340,000. It cannot be questioned that the general

business on the Ohio will be very much greater, and the tolls may thus be kept down to still lower rates.

Mr. Ellet in treating this branch of the subject, emphatically remarks: "It is scarcely to be doubted that the maintenance of a depth of 5 feet in the Ohio alone, at all seasons, would save the country from an annual tax upon its present business [7 years ago,] of five millions of dollars." It is evident that the rates of toll on the Ohio slackwater can be made lower even than they are on the Monongahela; and they are less on that improvement than they are on any other public work in the United States. The average on classed freight is about 5 mills per ton per mile, and on coal about 2 mills.

From the foregoing data we think it is shown, that the original cost of the slackwater, cost of maintenance, and the rates of toll that may be deemed necessary, do not constitute startling objections to the slackwater as a system. No radical improvement of so large a stream can be accomplished without considerable cost; the real question is, can it be effected in any cheaper or better manner?

6. *The sixth objection is*, "that the pools will fill up with sediment." This has been answered more than once, but at no time more beautifully than in the communication of Josiah Copley, Esq., to the Pittsburgh Board of Trade, dated January 15th, 1856. He says, "apprehension has been felt and expressed by some persons, that in time these pools will fill up more or less with sand and mud, and the channel be rendered too shoal for navigation; but these fears are groundless." * * * "On the Ohio, the inclined plane will be restored whenever the water raises to a height above 16 feet above the ordinary low water line; and that being the case, the velocity of the current will be the same as if no dams existed; for the water will be urged onward, in obedience to the law of gravity, with all the speed due to the natural fall of the river, just as it now is. This being so, its power to sweep its pools will be unimpaired, and consequently the debris cannot be deposited any more than it is now. In their natural condition, the Allegheny and Ohio are but a long series of alternate *dams* and pools—the ripples, as we call them, being nothing else than natural dams. The intervening pools or "eddies," as they are generally though improperly termed, are frequently thirty feet deep at the lowest water; yet the floods sweep them out, and they indicate no appearance of filling up.

"It is only in streams so small that no floods can ever restore the inclined planes broken by dams that we find pools filled up with debris. They never rise sufficiently high to restore the original velocity of the water in the portions of their channels occupied by these artificial pools; the consequence is, that whatever sand and mud are carried down from above, are deposited in this slackwater and remain there. In time the channel becomes so contracted, both in breadth and depth, that the stream in times of freshets, acquires its original velocity. After that no more sediment is permanently deposited.

"The Monongahela pools furnish a confirmation of the truth of the position here taken." And, it may be added, so do the pools of the lower Lehigh, the Juniata, the Kiskiminetas, the Beaver, &c. This objection appears to have no practical foundation. If it were applicable

at all to any dams yet proposed on the Ohio or Allegheny, it might have some force against those very high dams designed by Mr. Ellet to form a part of his artificial reservoir system, where the height of the dam would exceed the greatest natural rise of the stream, not permitting the river at any stage to be restored to its natural inclined plane, and where for much of the time these immense pools would be comparatively still. But even in this case the writer regards the objection as futile. Almost universal experience teaches, that no difficulty from this cause could arise on the Ohio River with pools of only eight feet lift, and floods of more than 30 feet height.

7. *The seventh objection is*, "That locks and dams will set a limit to the amount of freight which can be transported on the river."

In examining this we would call to recollection the fact that during about one-sixth of the time there will be a free, unobstructed navigation over the dams, both for ascending and descending craft; and that during half the time there will be a safe descending navigation over the chutes of the dams: it is believed that rafts may run them whenever they can run the Allegheny River, and that few *rafts* will pass through the locks. Much lumber will probably pass the locks in *barges* as a matter of choice. The coal business, as already suggested, will, from considerations of economy, be carried on largely through the locks in barges, towed by regular steam tugs; the barges will be arranged in fleets. The tug can take nine or more barges of 250 tons each, through a lock in 15 minutes. If we allow but one such fleet to pass per hour, it will give 54,000 tons per day, or an aggregate of eighteen millions three hundred and sixty thousand tons per year of 340 days! A quantity greater than is now shipped in the entire Union, on all the rivers, canals, and railroads. And yet but one-fourth the capacity of one of the double locks would be occupied. For the remaining three-fourths let us assume that four steamers may pass, each carrying 500 tons, or 2000 tons per hour, or 48,000 tons per day, or sixteen millions three hundred and twenty thousand tons per year. Making an aggregate of thirty-four millions six hundred and eighty thousand tons; without counting any tonnage that would pass over the dams. And what sort of a "limit" is this? The Charleston and Memphis, Baltimore and Ohio, Pittsburgh and Connelsville, Pennsylvania Central, Allegheny Valley, New York and Erie, New York Central, and all the great Canada railroads united could not accommodate the half of such an enormous trade. With double locks fifty per cent. more could be passed. The locks are not made with chambers so large—350 by 65 feet, merely capacious enough for a given or expected tonnage, but for the accommodation of the larger size of Mississippi steamers, so that they need not necessarily break bulk between New Orleans and the head of the Ohio. Practically, this objection on the score of limit of capacity of the locks has not the least weight; for should the business ever increase to the capacity of the double locks, it could certainly afford treble or quadruple locks, if required.

8. *The eighth objection is* expressed thus: "What, I ask, would be the condition of things if one of the fifty dams, which it is so lightly proposed to construct on the Ohio, should be washed away, or under-

mined, and the navigation there suspended for four months?" This may be taken as stating that the undermining or washing away of a dam would suspend the navigation four months—or some long period of time. The writer will take direct issue on this point, and affirm from his experience, applied to such a system on the Ohio River, that such result *cannot ensue.* There is very little danger that dams properly built, will actually wash away. But suppose a dam did wash away; it would at least leave the river along that part as good as it was in its natural condition. Yes, it would leave it rather better, on account of the back water from the next dam below. It would require the washing away of two consecutive dams to bring the river along that part back to its natural condition.

A dam may be undermined. Suppose it to be so, so that for several hundred feet of its length, or its whole length, it should sink two or three feet below the regular height, what would follow, practically? The cause of such injury would of course be a flood. So long as the flood continued the *navigation* would not be *injuriously* affected (by the sinking of the dam) either through the locks or over the dam. The navigation would not be affected until the flood had subsided, and the water had fallen so low as to leave a scant depth at the entrance of the next lock above. But mark, in the very nature of things, this depth could never be *less* than it would be in the natural river in a similar stage of water.

By the time the water in the Ohio had fallen so low as to afford insufficient depth at the lock above, the superintendent would have control of the dam below so as to keep up the pool to a proper height to maintain the navigation until the permanent repairs of the dam could be made. And if an entire dam and the locks at the same were swept away, what would be the consequence? The objection raised is intended to convey the impression that the navigation would *cease*, that all movement of vessels and craft of every kind would be stopped for months. We allege, positively, that it would not stop for one moment. The navigation along that particular portion of the river would continue as good as it was before the erection of the slackwater, and better. The peculiar advantage of the Ohio River slackwater, on account of its abundant supply of water, will be, that a serious injury of a portion of the works will not destroy the navigation. In almost any possible event, the repairing force on the improvement could, within 48 hours, make it passable for vessels, should an accident temporarily render it otherwise. Injury, so as to stop the working of both locks simultaneously—*at a time when steamers could not pass over the dam*—could alone stop the navigation. When the water was not high, such an event would be exceedingly improbable. The locks being all the same size and lift, the gates and all the parts of one would fit another. Ordinary prudence would dictate the keeping of a few finished gates and parts of gates, for such contingencies. In case all the gates of both locks should be carried away, an experienced superintendent could have one set replaced before the steamers should cease running over the dams; or, in case the accident happened at a low water period, within 48 hours after its occurrence. An objection to the Ohio slackwater on the score

of liability to injury—*so far as the navigation* of the river is involved—has much less weight than a similar objection to any canal in the country, where a serious break would absolutely stop the navigation.

It is an objection, that any work, merely human, is liable to derangement; but to press this too far against proposed public works, is neither wise nor politic. With equal propriety we may figure each of the proposed artificial reservoirs, and the great dams, as tumbling to destruction, bringing ruin in their train. The writer presents no such fear as an objection to them, although it must be conceded by every engineer that dams 50 or 100 feet high require more care, precaution, and extra cost to guard against accidents, on account of the largely increased pressure from the additional head of water. If this eighth objection is to be regarded as of much consequence, it must follow, that the proposed high dams on the Allegheny must be discarded, leaving the artificial reservoir system dependent entirely upon a series of comparatively small reservoirs.

The dams on the Monongahela were tolerably well built; they can be better built on the Ohio. The experience acquired on the former and elsewhere, can be advantageously applied in making a more perfect improvement; and with double locks throughout, there should be much less trouble and detention on the Ohio.

9. *The ninth objection is*, "That the dams which it is proposed to construct on the Ohio River, will convert the channel of that river into fifty stagnant and pestilential ponds, endangering the healthfulness and diminishing the population of its valley."

This objection has been gravely set forth, without any reference, however, to evidence showing where, in any analogous case, such an effect had been produced. It appears to be purely speculative. As a positive and complete refutation of this mere assertion, we may point to the Lehigh, the Schuylkill, the Susquehanna, the Juniata, the Kiskiminetas, the Beaver, &c., &c.; the valleys of which streams, have become *more* salubrious, more free from bilious epidemics, than they were prior to the erection of the dams. On the Monongahela, the health of the valley has been improved, and the population and business have been *immensely increased* in consequence of the slackwater. Mr. Ellet, in his original paper published by the Smithsonian Institute, took the correct, common sense view of this question when he said, "But the salubrity of rivers, when no longer subject to become dry, and have their sands and vegetable deposit exposed to the summer's sun, must necessarily be increased; for the same experience which teaches that large masses of fresh water, existing as lakes, are salubrious, also teaches that shallow stagnant pools, such as are found in the place of an exhausted river, are deleterious to health." This latter point of course had reference to the river in its natural state during periods of great drought.

The quantity of water that will be contained in the pools of the Ohio slackwater will be very great, and the healthfulness of the valley is much more likely to be improved than injured thereby. The ninth objection, on the score of health, appears to have less ground of support than any which has yet been named.

10. *The tenth objection is*, "That the delays at the locks will be greater

than the running time now required to make the trip ; and consequently the time now required for every ordinary voyage will be *more than doubled* by the detention at the dams."

This is a very strong statement, but fortunately it comes as a mere opinion. No attempt has been made to fortify it by facts, or from practical reasoning. *Facts*, go to prove the direct contrary, as will be shown. Facts, and legitimate reasoning, will both prove the reverse of the proposition so boldly put forth as an *objection* to locks and dams. We will first refer to a few facts furnished by a gentleman who, although not yet in favor of locks and dams for the Ohio River, is very familiar with the system and its operation on the Monongahela—Captain E. Bennett, who has been running steamers on that river almost ever since the completion of the improvement.—He says, "the time of running the 55 *miles*, including the passing of the 4 locks, varies from 6 hours down to 5 hours and 15 minutes by different boats. Generally it takes as long to go down as to go up. We count the time it takes, including all stoppages for freight and passengers, 8 hours up and 8 hours down. The average time required to pass each lock is from 7 to 10 minutes, but it can be done much quicker if required. A boat has been passed through No. 4 in a good stage of water in 2 minutes 20 seconds. We can land and put out a passenger and get under way again in from 2 to 3 minutes. Before the completion of the slackwater I do not recollect coming up (from Pittsburgh to Brownsville) in less than 12 hours, and frequently from 20 to 24." * * "We frequently make the trip, when the river is frozen to the thickness of three inches." * * "I think the ice does not form so quick in the pools in the first freeze as it did before the dams were built, owing to the greater body of water to be brought to the freezing temperature.

"I cannot say that the boats have been stopped by low water more than the summers of 1854 and 1856. In 1854 our boats were laid by 82 days, and a good part of that time there was no navigation for any steamboat of lighter draft (our boat draws 3 feet light). Our locks and dams have not caused much detention by being out of repair. We are occasionally detained for a short time by something getting behind or before the gates so as to prevent their opening or closing." We may hereafter have occasion to refer more particularly to the opinion (expressed by Captain Bennett in his letter) against the introduction of locks and dams on the Ohio. At present we merely wish to investigate the objection raised on the score of "*delays*."

The average length of the pools on the Ohio, with 50 dams between Pittsburgh and Cairo, will be 20 miles. A steamer in a round trip would pass 100 locks. Allowing the loss of time in passing each lock to be 12 minutes (which experience proves to be a very liberal allowance), the entire lockage time would be 20 hours—10 hours down and 10 hours up. A part of this should not be regarded as lost time, as many of the locks will be established as regular "*landings*," for passengers and light freight, which will be transferred during the passage through the locks. But for the present, let it all go against the slackwater system as lost time. During a considerable portion of each year, that is, whenever there is not more than a foot or eighteen inches of water flow-

ing over the wiers of the dams, the current in the pools will be very slight, so that the difference in the running rates of ascending and descending steamers will not be perhaps more than a mile an hour. And during this period the current is so gentle that steamers will land on their downward passage without losing time by rounding to. Assuming that there would be at least one intermediate landing, as frequently as every alternate pool, or once in 40 miles, it would give 25 descending landings per trip. Putting the loss of time caused by *rounding to* at 6 minutes, it gives 2½ hours saved in consequence of slackwater.

In he most favorable stage of the natural river, steamers on an average may run down stream about 14 miles an hour, and up stream about 8 miles an hour. The same steamers will *gain* much more in ascending through the pools than they will *lose* in descending the same. This is what experience and theory both establish. The difference even under the most favorable circumstances of the natural river, is at least worth noting; but as soon as the river falls to a 4 or 3 feet stage, this difference largely increases, in consequence of the delay in ascending the ripples, and in consequence of the delay in *descending* the same; for they dare not then run at full speed, to say nothing of the delays caused by grounding. The number of days when the water was below a 4 feet stage during the eleven years from 1838 to 1848 inclusive, was 1185, being an average of 108 days per annum. In one year, 1845, it was 139 days.

The number of days when the water was between 4 and 12 feet stage, was 2244, being an average of 187 days per annum, though in 1841 there were but 151 days. During the same period of eleven years, the average number of days when the stage of water was between 5 and 12 feet was 170, and between 6 and 12 feet, 146 days.

Navigation on the Ohio River may be roundly divided thus: 3½ months below 4 feet; 2½ months above 12 feet; and 6 months between 4 and 12 feet.

There will be 3½ months of the year when the slackwater will have greatly the advantage in the *time* of a trip; six months when the time of a trip would be almost equal; and 2½ months when they would be just equal, that is, when the steamers would run over the dams. But we have another fact to consider, namely, that for 2, 3, 4, or even 5 months of some years, large steamers *cannot now run at all;* and also times when the very smallest class steamers, carrying at prices more than double or treble high water rates, cannot run.

It is therefore unfair and unreasonable, in comparing slackwater with the natural river, to set down the time of passing the locks against the former without bringing into juxtaposition the other facts, which go to show that that delay is fully compensated for. If we state the actual daily performance on the Monongahela, where the dams are one-fourth more frequent or closer together than they will be on the Ohio, we shall find that in a round trip they make better speed than is made on an average on the Ohio in the natural river. This is an actual fact, which cannot be overlooked. What then becomes of the assertion, "That the delays at the locks will be greater than the running time now required to make the trip?" It was obviously made at a venture, without much calculation or investigation, and the statement is contrary to

all experience. It will be found on the Ohio, that although the downward passage in a good stage of water is made quicker on the natural river, that the upward passage will always be much quicker on the slackwater. It is easy to prove that this tenth objection, as stated, is a random suggestion: thus, the running time on an average, now required to make the round trip of 2000 miles, is, say, 80 hours down, and 125 hours up, equal to 205 hours: this gives a little more than 2 hours to each lock. According to this same sweeping mode of calculation, the *detention* alone at the Monongahela locks, ought to be over 16 hours; whereas, the steamers actually run the 110 miles, pass the locks, make all their landings, and complete the round trip in less than 16 hours! And yet these and similar assertions, must be gravely met, and their futility exposed, or they will be reiterated again and again.

11. *The eleventh objection is*, that "If dams are placed across the channel of the Ohio, all the trade of the river for 50 weeks of the year, will be forced through the locks." There are different ways of stating a question. This is one way. It admits, however, that there will be a *navigation* for 50 weeks of the year; the two weeks, it is presumed, being cut off on account of ice. Whereas, in the natural river, we have often no navigation. Now Mr. Ellet's calculations, and the records show, that for ten weeks there is a natural flow of over 12 feet water on the Wheeling bar, during which period all vessels can pass freely over the dams, without using the locks, if they should prefer it; and vessels of moderate draft may pass over them on many other days. As to being "forced" to use the locks, how gladly will business men avail themselves of the opportunity, when, without them, for so much of every season, they are now deprived of all navigation.

It is true enough, that even a perfect lock and dam navigation may not be so good as a perennial river with a steady six feet flow of water. Unfortunately, the Ohio River is very different from this. What value would a great railroad have, if it could only be used one half the year, at irregular, uncertain periods: and a part of that time, with only half trains, &c., &c.? On the other hand, could the Ohio River be made constantly reliable, with a natural flow, its value would be almost incalculable. There may be other minor objections to a slackwater navigation on the Ohio River; but scarcely any that can be worthy of grave refutation. Objections may be raised against any proposed public improvement; but in regard to slackwater navigation, it should be kept in mind that it is no longer an experiment; experience has sanctioned and established it as highly advantageous in certain cases. The real question is, are the solid objections to its introduction on the Ohio so great, that it cannot be made practically advantageous on that stream?

In the Appendix to this paper will be found some information, derived from practical sources, which the writer thinks will aid in arriving at correct conclusions upon some of the leading points belonging to this discussion.

We may recapitulate the chief points which the writer regards as tolerably well established; and first, in connexion with the plan of

Artificial Reservoirs.

That the annual flow of water in the Ohio at Wheeling if equalized is sufficient to afford a depth of 6 feet in the driest season.

That if "expense, damages, and health" be disregarded, it may be possible to construct reservoirs enough to effect it. That the estimate of the cost published by Mr. Ellet, is obviously altogether too low; and that even the greatly increased estimate of Mr. Morris, is quite short of the probable requirement.

That such large reservoirs as those described by Mr. Morris, cannot be advantageously located on the tributaries, and that sites containing all the elements designated, do not exist, either on the tributaries, or on the main streams; and that no where, above Pittsburgh, will six dams of 100 feet height contain half the quantity he has assumed.

That the advocates for artificial reservoirs, have made no allowance for evaporation between the reservoirs and Pittsburgh; although some of the reservoirs must be several hundred miles distant; nor have they made any allowance for the fact that on account of the greater declivity of the Ohio above Wheeling, a greater quantity of water will be required to maintain the same given depth.

That Mr. Ellet's estimate that 12 inches per annum from rains, &c., may be utilized, is safer than Mr. Morris's estimate of 18 inches; and that there are seasons, as shown by the flow at Wheeling, when even 12 inches would be an over estimate.

That the records at Wheeling, and the calculations of Mr. Ellet, prove that his proposed "regulating reservoirs" would be of no practical use in controlling great floods. That the two things—keeping up a regular navigation from reservoirs, and controlling floods—are incompatible; one demanding that the reservoirs shall be allowed to fill to supply the river in droughts, the other that they should be as nearly empty as possible, to be useful in holding back floods. The records show that in the great majority of floods, for eleven consecutive years, such reservoirs would have been full before the great floods came.

That to regulate the flow of the Ohio River to a uniform or to "nearly a uniform flow," would demand a vast array of reservoirs both on the main streams and on the tributaries; and that instead of being a "comparatively easy task," only requiring an expenditure "equal to a three years' cruise of three ships of the line," the cost would be enormous: and that such control of the Ohio could only be attained by the total destruction of interests greater than those it could by any possibility benefit; and that the same proposition, as applied to the Mississippi and Missouri Rivers, should fairly be regarded in an engineering sense, as *impracticable*.

And in all the foregoing calculations, the drainage of the entire area of territory above Wheeling, has been included; whereas, the actual drainage of the two rivers, Allegheny and Monongahela, is but a trifle over two-thirds of that area: almost one-third of the whole being derived from streams entering the Ohio River below Pittsburgh. The area

drained by the Allegheny is nearly two and a half times that of the Monongahela.

Secondly. In regard to the plan of low open dams without locks.

That this is only to be considered as a modification of the plan of artificial reservoirs, and as a means of saving water; and that although such a system might be available on the Ohio where the declivity gradually decreases from 12 inches per mile to 3 inches per mile, it would not be applicable on rivers of greater descent.

That if the artificial reservoir system be adopted, then the plan of low open dams should be more carefully investigated on account of the promise it seems to hold out of saving so much water.

Thirdly. In regard to the proposed

System of Locks and Dams.

It seems to be demonstrated, that there is at all times, even in the driest season known, an ample supply of water for slackwater purposes without resorting to artificial reservoirs: and that this is also proved by records and measurements which are undisputed! And that for the greater portion of every year, there will be a very large daily surplus, which may be made available for hydraulic purposes.

That by means of chutes in the dams, the descending navigation may be kept good for rafts and arks at those periods when the Allegheny River is in a favorable stage for the passage of the same craft.

That the largest steamers and also steam tugs towing numbers of coal barges, may pass the locks; and that the amount of trade which can be conveniently accommodated with a system of double locks, is so enormous, that it presents no real practical limit.

That the probable cost of a slackwater improvement of the Ohio, can be obtained in advance, approximately, with greater accuracy than in the case of railroads or canals, generally: and that it is not likely to exceed $12,000,000; and that the annual cost of repairs will not be likely to exceed $110,000 per annum.

That a rate of tolls which will scarcely be felt, will handsomely sustain the works.

That during nearly two months of each year, there will be a safe ascending and descending navigation over every part of the dams, when it will be optional for vessels to use the locks or not; that during three months of the year, or more, there will be a safe descending navigation through the chutes for rafts, &c.

That twelve feet rise in the natural river will create a depth of about five feet on the dams; 18 feet natural rise, about 9 feet; 24 feet natural rise, about 13 feet; 30 feet natural rise, about 18 feet; 36 feet natural rise, about 23 feet; 42 feet natural rise, about 29 feet; and 48 feet natural rise, about 35 feet on the dams. Thus, with the small rise of 12 feet, the dams will augment the height of the water above its natural elevation, more than six feet, while in the great flood of 48 feet, the dams would add only about one foot to the rise due to the natural river.

That always, before the locks will be submerged, the dams will be safely boatable, both for ascending and descending craft.

That injury to a dam can only improve the navigation *over the dam;* that it does not necessarily injure the navigation through the locks. A dam may be seriously damaged without interfering in the least with the navigation through the locks. Dams are not injured during low water; and not until the return of low water, could an injury to a dam affect the navigation at the locks: and then it is easy to keep up, temporarily, a sufficient height of water, until the injury may be repaired.

That nothing connected with a river lock, if properly constructed, except the gates, can be fairly regarded as liable to serious injury. And the locks being all alike, a few gates kept on hand, would obviate any great delay, even in the not very probable event of the destruction of the gates of both locks simultaneously. The loss of all the gates of but one of the locks, would cause no delay. Besides, such serious injury is only likely to happen during high water, when vessels would have free passage over the dams: giving time to perfect the preparations for the thorough repair of the damage.

That on a good slackwater navigation, taking the year round, first class steamers will make the trip between Pittsburgh and Cincinnati, or Cairo, &c., in *less time*, and at *less expense*, including tolls, than they can now; and that every steamer can make many more trips each year on the slackwater, than she ever could before. With the facility, certainty, and regularity secured by the slackwater, the aggregate annual trade will be immensely increased, requiring even more boats; each one more profitably employed than now.

That as a consequence of the increased safety and regularity, the rates of insurance may be greatly diminished. Collisions will be less likely to occur.

That the old fashion of conducting the coal business, between the Upper and Lower Ohio, and the Mississippi Valley, will, from choice, and from economical motives, be entirely abandoned. Barges will be substituted for the *frail arks*, which now not only never return, but in too many instances never reach their destination. Consequent upon this change, the coal business will rapidly and largely increase, beyond the calculations of the most sanguine—to the advantage of the consumer as well as the producer; regulating the price to a nearly uniform rate throughout the season, and incidentally giving the coal operators more complete control over their mining hands: at the same time it will be better for the miners.

That the improved slackwater navigation will soon induce a considerable change in the mode of carrying on the *lumber trade*. Large amounts of lumber, logs, &c., will be taken from the water in the vicinity of Pittsburgh, to be seasoned and partially worked, and afterwards shipped on *barges* to the various points in the great Mississippi Valley; where the demand, to the third generation, must be an annually increasing one.

That the locks, in time, will all become passenger landings, as well as points for light freight, and many of them for general business; thus reducing to some extent, the number of other transient landings.

That it may be safely assumed that after the completion of a perfect

slackwater navigation, the *average* rate of freights on the Ohio, and consequently between the Ohio and all points in the great valley along the rivers, will be *materially reduced.*

General Conclusions.

1. The writer has attempted to show to others, what he believes, that there are great practical difficulties in the way of so extensive a system of artificial reservoirs as would be necessary to supply the natural bed of the Ohio River with six feet depth of water all the year; nor does he assume by any means to have exhausted this branch of the subject. But if it can be shown that the reservoir system, *for such a purpose*, is really practicable, even at a cost of $20,000,000, the *cost* should not prevent its adoption.

2. The Ohio River has *four times* as much descent per mile between Pittsburgh and Wheeling, as it has near its lower portion below Evansville; it also becomes gradually wider, though not in proportion to the diminished declivity. From this, two things would seem to follow: first, that on the reservoir plan, it will require *more* artificial supply of water at the upper end than would be needed at the lower end, especially if, as we think, the lower portion of the river is better fed naturally from the side tributaries; and second, that on the slackwater plan it will require *less* water at the upper end than below, for two reasons—having shorter dams, causing less leakage—and narrower pools, making less evaporation towards the upper portion of the river.

3. After a complete investigation of the subject, it may be found, that the plan for keeping up the flow of the river in its natural state, may be regarded as impracticable; in that event it does not follow, that the plan of low open dams, requiring only *one-third of the water*, should also be deemed impracticable; the question might then stand between the plan of low open dams and the slackwater plan. If the water supply for the open dams should be demonstrated as fairly practicable at a reasonable cost, judgment might still be given in favor of the low dams without locks, notwithstanding certain objections.

4. It is obvious, that the necessity for a radical improvement of the Ohio, is becoming greater every year, with the increase of railroad facilities between the Ohio Valley and the Atlantic coast, and with the very general and truly wonderful annual increase of population and trade of the great Mississippi Valley.

5. That even at present, the aggregate annual losses to the cities, towns, and contiguous country directly interested, and mainly dependent upon the Ohio River as an avenue of commerce, added to the loss to steamboat owners, coal operators, coal dealers, &c., from the failure of a single season's navigation, such as occurred in 1856, would amount to a very large proportion of the gross cost of permanently improving the river. No fact seems better settled than this.

6. Whilst it is no easy task to determine how the river can be best improved, it is desirable that the subject should be investigated and reported upon in such a manner as *to command the respect and confidence of the country.* Experience, every where, teaches the danger of *merely*

legislative decisions of such questions, though it is the legitimate province of Congress to provide for their thorough *investigation* and determination. Congress, at its last session, acted upon this subject; but owing to various causes, the bill which passed one branch, was not reached in the other, and failed to become a law. It is to be hoped that at the coming session a proper law will be enacted, providing for such an enlightened commission as will be able to settle the question finally.

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Although the quantity of water required to maintain a steady flow of any given depth through open sluices of regular width, may be calculated with considerable accuracy, yet in the case of an open river of an uneven section, irregular in width and declivity, it cannot be expected that any more than a rough approximation can be attained: more uncertainty must necessarily attend the measurements, and consequently, the results founded thereon. Whether this should operate in favor of, or against the proposed plan of supplying the Ohio River by artificial reservoirs, is a question which the writer leaves to the determination of others: all who have read Mr. Ellet's papers can judge for themselves. His calculations are based on measurements made at Wheeling, where the declivity of the river is considerably less than at a number of points above Wheeling. It seems fair to infer, that a quantity of water that would give six feet depth at Wheeling, would not give so great a depth at certain points higher up.

Upon a critical examination, it may be found that much more water would be necessary, than we have hitherto assumed in the course of this investigation, to secure six feet depth between Pittsburgh and Wheeling.

Again, respecting the drainage, Mr. Ellet remarks in regard to the drainage of 1844, which was 11·32 inches, according to his approximate estimate, that it is "almost precisely the amount ordinarily assumed by engineers as the supply that may be relied on for canal feeders, *but by no means that which ought to be uniformly anticipated.* There is, in fact, scarcely an approach to uniformity in the annual discharge of streams in this climate." Ample exemplification of this, as a general fact, may be seen on an examination of rain tables in almost any part of the world, where the rainfall has been registered.

Early European Views of Plans of Reservoirs for Supplying Rivers.

In a work written by Mr. Thomas Telford, about the year 1800, he discussed the question of the improvement of the navigation of the River Severn. It is thus mentioned in Rees' Cyclopædia. "Mr. Thomas Telford has (page 288,) proposed another method of improving the Severn River, by collecting "the flood waters into reservoirs, the principal ones to be formed in the hills of Montgomeryshire, and the inferior ones, in such convenient places as might be found in the dingles and along the river. By this means, the impetuosity of the floods might be greatly lessened, and a sufficient quantity of water preserved to regulate the navigation in dry seasons, &c. This, it is thought, might even prove the simplest and least expensive mode of regulating *navigable rivers*, especially such as are immediately on the borders of hilly countries."

Mr. William Jessup, on another occasion, says, "rivers may be rendered nearly uniform throughout the year by reservoirs."

Mr. Rennie, an engineer of the first reputation in his profession, remarked: "After what has been said respecting the excess of flood water in the River Roch above the ordinary supply, the *idea of correcting the floods of the Severn* by reservoirs, must appear to be ridiculous."

The Severn, although a considerable stream in England, is greatly inferior in size, extent of drainage, height of floods, &c., to the Ohio. In its low stages, however, it assimilates very nearly to the low stages of the Ohio.

The whole length of the Severn, up to Welshpool, is 155 miles, while the Ohio, up to Pittsburgh, is 1000 miles. The highest floods in the Severn were about 16 feet—the average height of floods about 7 feet: while the highest floods in the Ohio are from 40 to 60 feet, and the average height of floods is over 20 feet.

There may be some rivers in England, and some in the United States, which would admit of material correction, or control, by means of reservoirs, but does it hence follow, that it is practicable to govern or control all rivers? The entire territory of Great Britain is much less than the area of country drained by the Ohio River. The drainage of the Ohio, above Wheeling, is about half the area of all England. When Mr. Ellet published his "Physical Geography of the Mississippi Valley," in 1849, he was not probably aware that the same plan for improving and controlling rivers, had been formally proposed, nearly sixty years ago in England, as above quoted.

There is some coincidence between the calculated drainage of the Thames River, in England, and the Ohio River above Wheeling, which may be worth a passing glance: thus, in England, with 6000 square miles of drainage, the average annual flow from the Thames, is assumed by Dr. Halley, at 166,624,128,000 cubic feet; the average annual flow as deduced by Mr. Ellet for the Ohio River drainage above Wheeling, (25,000 square miles,) is 835,000,000,000 cubic feet; one showing 27,770,688 and the other 33,400,000 cubic feet per square mile.

According to Mr. Ellet's calculations, to have regulated the supply of the Ohio in 1848, it would have required reservoirs capable of containing fifty per cent. more than *the entire flow of the Thames for a year.* But it has been shown in the text, that uniformity could not have been secured even with reservoirs of this great capacity.

Appendix A.—Fall of Rain in Various Places, Drainage, &c.

"The mean quantity of rain falling annually at 147 places, situated between north latitude 11°, and 60°, deduced from tables kept at those places, is 34·7 inches." (From a paper published by M. Cotte in the (*Journal de Physique*, for Oct., 1791.)

" The mean annual quantity of rain is greatest at the equator, and decreases gradually as we approach the poles, thus at

Granada, Antilles,	12°	North Latitude	it is	126	inches.
Cape François, St. Domingo,	19° 46′	"	"	120	"
Calcutta,	22° 23′	"	"	81	"
Rome,	41° 54′	"	"	39	"
England,	33°	"	"	32	"
Petersburgh,	59° 16′	"	"	16	"

"On the contrary, the number of rainy days is smallest at the equator, and increases in proportion to the distance from it.

"From north latitude 12° to 43°, the mean number of rainy days is 78, from 43° to 46° the mean number is 103; from 46° to 50° it is 134." * * * " And more rain falls in mountainous countries than on plains."

We find in Gregory's Dictionary of Arts and Sciences, some interesting information compiled from the transactions of different learned societies, giving results shown by rain gauges kept at different places in England, through a series of years, varying from one to twenty-one years.

The average annual fall in 23 places, registered as *maritime* counties, was 38½ inches; while, in 7 places referred to as *inland* counties, the average annual fall was 24 inches.

Among the maritime counties, the highest recorded was at Keswich, in Cumberland County, 67·5, average of 7 years; the lowest at Carlisle *in the same county*, 20·2 inches one year.

At Liverpool, 18 years average 34·4 inches.

At Manchester, 9 years average 33·0 inches.

Among the inland counties, the highest recorded average was at Chatsworth, 15 years 24·8 ins., and the lowest at South Lambeth, 9 years 22·7 ins.

The mean annual average in London, 7 years, was 23 inches.

From the foregoing, it will be observed, that while in the maritime counties, the mean average in different places *varied* to the extent of 47·3 inches, the variation in the inland counties was but 2·1 inches; a remarkable difference, and the average mean annual fall in the maritime counties was 60 per cent. greater than in the inland counties. Thus, in a comparatively limited area, not exceeding that of one of our larger states, in thirty different localities, these great variations occur; some portions of the territory receiving more than three times the rainfall of other portions, even in the maritime counties; while in the inland counties there is a singular uniformity, and very much less rain. We infer that in making calculations for reservoirs in England, it would be necessary to attend critically to the records of a rain-gauge, or the measurements of the streams flowing from the particular regions in question.

In regard to a great number of local reservoirs to be established at widely separated points along the head waters of the Ohio above Wheeling, embracing an area nearly half as large as England, some attention would seem to be necessary to determine the local characteristics of each

separate region. We know from records kept by the United States officers at numerous points, that the variations in our country are even greater than they are in the European tables just quoted; running from 3 inches to 76 inches per annum; occupying, however, a much more extensive area.

On the Pacific coast, within 600 miles of each other, one post, Fort Orford, has the maximum 68·52 inches, and the other, Fort Yuma, the minimum 3·24 inches of the rainfall recorded.

The following Table is extracted from the "Army Meteorological Register," and presents the results at various points for 33 *years, from* 1822 *to the close of* 1854. *It is only a portion of a larger table.*

	Latitude.	Longitude.	Elevation above the sea in feet.	Average annual fall of rain in inches.
Fort Kent, Maine,	47°15′	68°35′	575	36·46
Fort Preble, "	43 39	70 20	20	45·25
Fort Constitution, N. H.,	43 04	70 49	40	35·57
Fort Independence, Mass.,	41 21	71 09	50	35·30
Fort Adams, R. I.,	41 29	71 20	40	52·46
Fort Hamilton, N. Y. Harbor,	40 37	74 02	25	43·65
Plattsburgh Barracks, N. Y.,	44 41	73 25	186	33·39
Fort Ontario, N. Y.,	43 20	76 40	250	30·88
Fort Niagara, "	43 18	79 08	250	31·77
Allegheny Arsenal, Penna.,	40 32	80 02	704	34·96
Carlisle Barracks, "	40 12	77 14	500	34·01
Fort Mifflin, "	39 53	75 13	20	45·27
Washington, D. C,	38 53	77 02	70	41·20
Fort Monroe, Virginia,	37 00	76 18	8	50·89
Augusta Arsenal, Ga.,	33 28	81 53	600	23·00
Fort Pierce, East Fla.,	27 30	80 20	30	62·98
Fort Pike, La.,	30 10	89 38	10	71·92
New Orleans, La.,	29 57	90	10	50·90
Fort Smith, Ark.,	35 23	94 29	460	42·10
Fort Gibson, Ind. Ter.,	34 47	95 10	560	36·46
Jefferson Barracks, Mo.,	38 28	90 15	472	37·83
St. Louis Arsenal, "	38 40	90 05	450	41·95
Detroit, Michigan,	42 20	82 58	580	30·07
Fort Mackenac, "	45 51	84 33	728	23·87
Fort Winnebago, Wis.,	44 30	88 05	620	34·65
Fort Des Moines, Iowa,	41 32	93 38	780	26·56
Fort Atkinson, "	43	92	700	39·74
Fort Snelling, Min.,	44 53	93 10	820	25·43
Fort Leavenworth, Kan.,	39 21	94 44	896	30·29
Fort Kearney, Nebraska,	40 38	98 57	2360	27·98
Fort Laramie, "	42 12	104 47	4519	19·98
Fort Worth, Texas,	32 40	97 25	1100	40·86
Phantom Hill, "	32 30	99 45	2300	17·22
Fort Croghan, "	30 40	98 31	1000	36·56
Fort McIntosh, "	27 31	99 21	400	18·66
Fort Webster, New Mex.,	32 48	108 04	6350	8·79
Fort Conrad, "	33 34	107 09	4576	6·76
Albuquerque, "	35 06	106 38	5032	9·42
Fort Yuma, California,	32 43	114 36	120	3·24
Monterey, "	36 36	121 52	140	12·20
Fort Humboldt, "	40 46	124 09	50	16·77
Fort Orford, "	42 44	124 29	50	68·52
Fort Dallas, Oregon,	45 36	120 55	350	14·32
Fort Steilacoom, Wash. Ter.,	47 10	122 25	300	51·75

The great variations exhibited between points but a few miles apart, prove the same thing shown by the records of the flow of water at Wheeling; that the rainfall is entirely irregular, and that the results obtained from the most careful observations at any given locality, cannot be assigned to any other point. Hence, in the opinion of the writer, an extended system of rain gauge observations among the head waters of the Ohio, would not be likely to present any more reliable data than the records of the actual flow at Wheeling already shown, except for special localities. Indeed, this would seem to present a better approximation for general calculations, considering the object in view, than the records from rain gauges.

Mr. Ellet makes the annual average flow at Wheeling equivalent to a depth of 14·778 inches over the whole area of country drained. But one year, 1845, gave but 9·83 inches. In 1844, it was only 11·52 inches. Thus two consecutive years gave less than 12 inches.

In calculations designed to form the basis of a system dependent *entirely* upon the annual downfall of water, would it not be prudential to assume the *lowest* annual result, as an event to be anticipated? Thus, in placing a reservoir, we should allow sufficient area of territory above the dam, to barely fill it once a year with the minimum of 9·83 inches, in preference to assuming the larger result, 18 inches: otherwise, we may expend money uselessly. In the absence of long continued observation of the actual fall in any given locality, this would appear to be the only safe guide.

In regard to the great reservoirs proposed on the main navigable rivers, it is different, because we know beforehand, that all of them combined, will not contain the drainage of the driest year.

There is another point connected with the failure of water and storing up in reservoirs, not adverted to by the advocates of the artificial reservoir system. Having theoretically set apart 3600 square miles (out of about 25,000 square miles,) which represents the artificial source of supply needed to maintain a six feet stage in the river for a given number of days, it must follow, that it will not be quite sufficient in practice. If this additional supply originated outside of the area already included, the calculations would be correct, but being a part of the same natural flow, the retention of one-seventh would add a per centage of days to the low water period.

In 1845, had the whole drainage been stopped in one immense reservoir, and drawn out daily in equal quantities throughout the year, it would have afforded only 7 feet depth on the bar at Wheeling. And yet there was not a single day that year, when it was less than 2 feet 4 inches, and not a month, when the average was less than 2 feet 10 inches on the bar.

From these considerations, we think that an assumption of 12 inches per annum as the downfall of water that may be utilized in reservoirs in the region named, is quite liberal enough.

Appendix B.—Facts Connected with Dams and Rivers.

Monongahela River.—Below Brownsville the river banks are generally from 30 to 50 feet high, except two or three instances, where they are not more than 25 feet. The average width of the river is 900 feet.. The lower bottom lands seldom exceed 300 yards in width, on one side only; the *widest* being less than half a mile near Pittsburgh.

Above Brownsville, thence to the State line of Virginia, the river banks are from 35 to 55 feet high. The average width of the river is 600 feet. The lower bottom lands from 50 to 200 yards wide, on one side only.

Kentucky Rivers.—The following information was furnished by Sylvester Welch, Esq., Civil Engineer, to the writer in 1839. Mr. Welch at that time was Chief Engineer of the State of Kentucky.

"The floods in the Green River rise from 40 to 50 feet, and in the Kentucky River from 30 to 55. The Licking River having more descent seldom rises over 40 feet.

"There are several mill-dams upon the Licking from six to ten feet high. When the river rises from eight to twelve feet, or higher, (about five feet on the dams,) *flat boats with full loads* of iron, or agricultural produce, pass over them without inconvenience. When the water is five feet or more upon the wier of the dams, the surface below rises so as *nearly to coincide* with the surface above. *A canoe could then pass with safety.*

"When we can do so conveniently, we make the lifts of our locks about fifteen feet, but they vary from *ten* to *eighteen.*

"All the works in our rivers will be covered with water during high floods. We raise our lock walls ten feet on the Kentucky, and eight feet on the Licking, above the top of the dam. The abutments will be raised a little higher than this.

"When the water runs so as to be *eight or ten feet* deep on the weir of the dams, the surface below will come up *nearly to the same level* as that above, (the fall will be distributed along the pool,) and steamboats may pass up or down over the dams. When the water rises much above this, there will be no perceptible difference between the level of the surface above and below the dam, and the current will not be strong enough to act injuriously upon the banks of the river, or upon the works connected with the dams."

The following facts were derived during the same year, (1839,) from Edward F. Gay, Esq., Civil Engineer. They are contained in his report relative to a survey he made along the Allegheny River, in 1828. These remarks refer to the slackwater navigation on the Conestoga navigation, constructed by him; and they are the result of practical observations. He states, "that previous to the improvement of that stream, high-water marks were seen along its banks from *ten* to *twelve* feet above the surface of common low water. This was said by all to be the usual height of the freshets; and from this fact, the possibility of constructing permanent dams on the stream was doubted by many. The dams, however, were built, varying in height from *ten* to *fourteen*

feet above the bed of the stream; and in no instance since their construction has a rise of the freshets in the ponds exceeded *three* feet; whereas, in the unimproved parts of the river, the same complaints are heard of its rise as formerly.

"This extraordinary difference is easily accounted for by its increased surface in the pools, and its unobstructed discharge over the dams."

On the same subject we would present some extracts from the report of Sylvanus Lothrop, Esq., who was the Chief Engineer of the Monongahela slackwater navigation in 1846. "It affords me great satisfaction to be enabled to state, that since the last annual report, the navigation has not been interrupted or delayed in a single instance, by the breaking or failure of any part of the works or fixtures connected with the improvement, but has continued in successful operation at all times, when free from ice, except on a single occasion, and that *for one day only*, when it was partially obstructed by a flood in the Monongahela, so high as to cover two of the locks, *and to enable steamboats* to pass over the dams." "The walls of the locks being *ten* feet above the combs of the dams, it would require a rise of *more than* 20 *feet* in the natural condition of the river to submerge them. It may be proper, however, to remark in connexion with this circumstance, that, so far as the public is concerned, a casualty of this sort, how frequently soever it might happen, would be attended *with no inconvenience* to them whatever, as the boats and other craft engaged in the navigation can always pass over the dams, whenever, and even before, the operation of the locks is suspended by high water. The principle which has heretofore generally been admitted, is now *ascertained by actual* experience and observation to be correct, that whenever the waters of the Monongahela swell to an elevation of *eight feet upon the combs* of the dams, they *then cease to back the water*, and the flood is no higher in consequence of their erection. The fall being then distributed along the pools, and the surface nearly equalized, both above and below, they can be passed in either direction by steamboats of the largest class employed in the trade, without hazard or delay."

Comment upon such facts, thus clearly presented, would be superfluous. But in justice to Mr. Lothrop, another extract from the same report seems proper, as containing the views of a gentleman of admirable cool judgment, and great practical experience. Mr. Lothrop says, "There is another point of view, however, in which this work may be considered important to the country at large. Its successful completion and opening (although under circumstances the most adverse,) at an expense scarcely one-half of that of our ordinary lines of canal, while its capacity for business is so immeasurably greater than any work of that description which has ever been constructed, are calculated to furnish another striking illustration of the advantages of this species of improvement, and thereby to lead to the earlier development of the susceptibilities of our Western streams. To the Ohio River itself, which is the common highway of so many States, and to many other of its most important tributaries, its applicability will be found, on examination, to be not less apparent, than to the Monongahela."

We take the following from the Ninth Annual Report of the President of the Monongahela Navigation Company:

"The stockholders will no doubt be gratified to learn, as the Board are to inform them, that, as in former years, no interruption has occurred in the navigation for a single day, from any of those causes to which this improvement was supposed to be so peculiarly exposed; high and low water have proved alike harmless; while the favorite idea of a long obstruction from the formation of ice upon its deep and quiet pools has been exploded by the fact that, for the *last three winters*, the boats employed in the trade have been making their daily trips to Brownsville, *while the river was locked up by ice beyond that point*." A fact like this is of more practical value than any theory, however beautifully elaborated.

Extracts from the Report of the President of the Monongahela Navigation Company, dated January 6, 1851:

"On the third day of November, 1844, your navigation was completed, (29 miles had been completed and in use four years longer,) and the locks opened for the passage of boats; and during the period that has since elapsed, of more than six years, it has been *subjected to the severest tests of floods and ice* without suffering any material injury, or requiring any extraordinary repairs, and is now in good order, thus giving the strongest demonstration of the strength and durability of the work.

"The amount of toll collected during the six years since the completion of the work, is as follows, viz:—

For the year 1845,	$28,579·70
" 1846,	43,422·39
" 1847,	54,261·90
" 1848,	56,623·93
" 1849,	53,756·32
" 1850,	64,318·31

"The shipment of coal increased from 4,605,185 bushels in 1845 to 12,297,967 bushels in 1850.

"It is gratifying to be able to state, that during the year 1850, the *navigation was not suspended a single day by ice or any other obstruction*."

Probably no canal in the United States, at any period of its history, can claim such exemption from interruption.

Mr. Ellet, in his *eighth* objection to locks and dams, founds it mainly upon an accident which occurred at one of the locks on the Monongahela, in 1851, which interfered with the navigation four days. In order that all who feel interested should be able to judge how much weight it is entitled to, an extract from the Annual Report of Gen. Moorhead, President, dated January, 1852, is here given.

"The obstruction referred to, was the result of a forcible displacement of the lower gates, occasioned by an ascending boat, while the steamer *Atlantic* was in the act of passing in the same direction through the upper ones. Through some mistake or mismanagement on the part of the pilot of the former, she was driven by the force of steam against the lower gates, with such a momentum as to force one gate upwards against the full head of water, while its fellow, left without other support than the mitre sill, and exposed to the whole force of the accumulated flood,

was swept downward and torn from its fastenings by the violence of the current. The effect was, of course, to close the upper gates at once upon the *Atlantic*, with a force that held her there as though she had been compressed by the jaws of a vice, while the torrent rushed through the lock with all the force and velocity which a head of eight feet would naturally impart to it. Fortunately, however, a pair of new gates was *in course of preparation* and *nearly* completed; and although the extrication of the steamboat, and the shutting off the water from the lock proved to be a laborious and expensive task, it was successfully accomplished, and the new gates suspended, under the personal superintendence of the President, within four days of the occurrence of the accident."

"In order, however, to provide against the recurrence of any similar casualty, arrangements were made for the preparation of extra gates."

In Mr. Ellet's reference to this, as a disaster to be apprehended on the Ohio, he inadvertently states that the gates were *ready*, whereas, they happened to be only nearly ready. But now, when we see a navigation successfully carried on for over seventeen years, with but a solitary accident of this nature; and when we know that all public improvements having locks where steam is used are subject to the same, and we hear of no fellow to such an accident, how much consideration should be given to it in a comparison of the advantages and disadvantages of a great system!

In the same Annual Report, it is stated, that "the excessive cold with which this region has been visited, at the commencement of the present winter, resulted, as might have been expected, in locking up the whole river, and entirely suspending navigation as early as the 17th of December." "A like occurrence took place in 1846, when the navigation was interrupted for a period of three weeks; and then, as now, the *accumulated masses of ice passed off without doing* any material damage to the structures under our charge.

"Since the winter of 1846, until the present one, navigation has never been suspended three days at one time in consequence of ice; and judging from past experience, we may not anticipate a similar interruption for many years to come."

Drought, 1854.—In 1854 there was a great drought. It is thus mentioned in the Annual Report of the President of the Company, of January, 1855:

"In July, however, the effects of the drought began to be felt; and on the 27th of that month, the water became so low that the large packet boats ceased to run during a period of nearly three months, and were not able to resume their trips until the 17th of October. During a part of that time, however, smaller boats were run; but the water was still so low, that even they could carry little or no freight, and the common coal flats could not be towed over the improvement with full loads: in fact, business upon the river during that period was virtually suspended, *an occurrence heretofore entirely unprecedented.**

"A slight rise about the middle of October enabled the packets to resume their trips; but the water did not rise sufficiently to let out the

* When the navigation had been in use fourteen years.

coal boats, which were loaded for the western markets, until after Christmas.

"Many of these boats were loaded in May, and kept afloat at the expense of their owners during the entire summer and fall. The water, during the greater part of that time, not only ceased to run over the dams, but by evaporation and leakage became almost literally dried out of the pools."

1855.—Extracts from the sixteenth Annual Report of January, 1856.

	STATEMENT OF COAL BUSINESS.	
	Number of bushels.	Amount of tolls.
1845	4,605,185	$ 5,283
1846	7,778,911	10,221
1847	9,645,127	13,241
1848	9,819,361	12,438
1849	9,708,507	13,533
1850	12,297,967	17,023
1851	12,529,228	17,850
1852	14,630,841	20,014
1853	15,716,367	21,291
1854	17,331,946	25,079
1855	22,234,009	31,050

"An examination of the quantity of coal that passed the improvement during the last year, and the revenue derived from it, shows the toll to be but *one mill and four-tenths* per bushel, or less than *four cents* per ton! A tax so inconsiderable should not be complained of, particularly as the construction of the improvement has greatly augmented, if not created, the business." *Yes, it created it!*

"Another important feature in the coal business worthy of remark is, that the transportation of it to Cincinnati, Louisville, and many other places, is *now done in barges* instead of the old-fashioned boats. These barges are towed down and back by steamboats built for the purpose." "By this means the cost of boats is saved. A great saving is also effected in running them, as one steamboat will tow down from eight to twelve barges, and the same number back empty. It is believed that by that mode, coal can be delivered from one to two cents per bushel cheaper (28 to 56 per ton,) in western ports than by the old system. When the Ohio River is improved by the construction of an artificial navigation, as it should and it is hoped will be by the aid of the General Government, these coal barges can be run during the entire season, except when navigation is suspended by ice. The regularity with which coal could then be supplied, would increase the demand to an unlimited extent."

"The Board are pleased to see public opinion turned to this subject. It is one of great and national importance, and passing, as the Ohio River does, through six States, commends itself to the fostering care of the General Government."

1856.—The year 1856 was a memorable one, not only on the Monongahela River, but on all western streams, and especially on the Ohio and Mississippi rivers. All were much lower than they were ever known to

be before, while the interruptions from ice were also beyond all precedent. Thus from January 1st to March 23d, and from December 21st to December 31st, making 94 days, closed by ice during the year 1856.

From 1845 to 1855 inclusive, eleven years, the average annual interruption from ice was but 20 days, whilst in the single year of 1856, there were 94 days. This shows most strikingly the great severity of that winter.

But this was a year of disaster to the navigation company. "On the 14th of May a breach occurred in Dam No. 2, carrying away nearly two hundred feet in length of that structure, which greatly interrupted the navigation. Immediate and active measures were taken to repair it, and the work was accomplished at an expense of more than seventeen thousand dollars. The river commenced falling immediately after this disaster occurred, and with the exception of a slight rise of about two feet, during the progress of the work, the stage of water was very favorable for making the necessary repairs. After these were completed, and the navigation resumed, the river continued to fall, until the water became so low in the different pools, as to suspend the navigation entirely: [*drought*,] and from the 14th of May until the 1st of December, a period of more than *six months*, there was at no time a sufficiency of water either in the *Monongahela* or *Ohio* rivers to float coal boats."

" Some idea of the extreme lowness of the river may be gathered from the following statistics, which are so remarkable as almost to challenge belief; but as the measurements were made with great care, at different points, and by different persons, and corroborate each other, they form strong proofs of the facts."

"Below Dam No. 4 [a few miles below Brownsville,] the water was gauged by the President of the company, on the 1st day of October, 1856, and the quantity passing per minute, was found to be but 1492 cubic feet. Mr. Charles Stewart, the Engineer, gauged it at the Brownsville Bar, on the 8th of October, 1856, and the quantity passing per minute was 1365 cubic feet. In 1838, W. Milnor Roberts, Esq., gauged the Monongahela at its lowest stage, and ascertained the quantity passing to be, per minute, 12,000* cubic feet—more than eight times as much as either of the above measurements. Charles Ellet, Esq., made examinations during the summers of 1843, 1844, and 1845, at the Wheeling Bar, and the minimum quantity reported by him was, September 30th, 1844, about 70,000 cubic feet per minute. Nothing could more forcibly illustrate the extreme lowness of the water than these figures; and as the great drought of this year continued for so long a period, it satisfactorily explains the small receipts of the Company."

*The measurements which gave 12,000 cubic feet per minute, was above, but near *Pittsburgh.*

It is true, that one of the measurements of the writer at Brownsville, August 30th, 1838, gave 12,420 cubic feet per minute. It was, however, measured again, September 19th, and found to be 4500 cubic feet, and this was the *actual* period of the lowest water during that extraordinary season.

APPENDIX C.—DISINTERESTED TESTIMONY.

Time of passing Locks, Cost, &c.

Extract from a report published by a company of gentlemen who made an excursion of examination along the Monongahela Improvement in 1845, after the entire completion to Brownsville.

"The subscribers were especially pleased with the opportunity afforded them, of examining the substantial workmanship of the locks, and the admirable machinery by which the gates are worked on the Monongahela slackwater. They were both surprised and gratified to find that the very large locks could be filled, and the steamboats passed through each of them, with a detention not exceeding SIX MINUTES. They were thus fully convinced, that a durable improvement has been made, which secures safe and rapid communication between Pittsburgh and Brownsville, except when closed by ice."

The names appended, are, N. B. Craig, Esq., Hon. R. C. Grier, Hon. John C. Plummer, John Anderson, Esq., B. B. Hart, Esq., Philadelphia, Henry Hall, Esq., Balt., Lieut. John Rodgers, U. S. N., C. H. Fuller, Civ. Eng., Hon. James Bell, C. W. Smith, Esq., N. O., E. J. Martin, Louisville, Col. Robert Orr, J. L. Neff, Maryland, Lieut. J. L. Parke, U. S. N., John D. Davis, William Eichbaum, Josiah King, and others.

And yet, without regarding evidence of any kind, and the experience of twelve more years of successful navigation on that work, the opponents of the lock and dam system, continue to assert, though without any proof whatever, that hours instead of minutes are to be consumed in the passage of a single lock. And in regard to cost: a new lock, with chamber 250 by 56 feet, planned in 1852, by Sylvanus Lothrop, Esq., then Chief Engineer, was estimated to cost $45,000.

In 1853, the company determined to extend the slackwater from Brownsville to the Virginia State line, and thus refer to it in their report of January 2d, 1854:

"An accurate survey of the river from the mouth of Red Stone Creek to the State line, was made in September last, by John White, Esq., a highly competent engineer. The entire ascent to be overcome by the dams, is 41·8 feet, corresponding very nearly with the original survey made in 1838, by Mr. Roberts. Mr. Lothrop, the Engineer of the company, proposes to overcome this by three dams of *fourteen* feet each, which have been located by him and the President, as follows:

"No. 5, at Bennett's Bar, 2 miles above Brownsville.

"No. 6, at Rees's Landing.

"No. 7, at Jacob's Creek, lower ripple.

"It is believed that the three locks and dams can be constructed, for cash, for about one hundred and fifty thousand dollars." But $50,000 each!

These dams are five feet higher than those proposed on the Ohio river, being 19 feet from the bed of the stream, and 14 feet from the pool—the height from pool to pool being 6 feet more than on the Ohio. They are therefore necessarily more costly structures *per foot of length*, though only

about half the average length of the dams proposed on the Ohio. The locks will also have 6 feet more lift than those proposed on the Ohio; other dimensions being equal, the additional lift would, of course, increase the cost. From this it may be inferred that the estimate of cost in the Ohio, as contained in the paper of the writer, is liberal.

APPENDIX D.—FACTS IN RELATION TO NAVIGATION ON THE OHIO RIVER.

The following letter in answer to certain interrogatories submitted by F. R. Brunot, Esq., of Pittsburgh, is from one of the most experienced and reliable captains navigating our western waters.

Between Pittsburgh and Cincinnati.

1. The best stage of water for the packets would be about 15 feet at Pittsburgh and 20 feet at Cincinnati.

2. From Pittsburgh to Cincinnati, time down about twenty-eight to thirty hours. Has been done in 27 hours down, and 44 hours and 57 minutes up.

3. The average landings down in a business trip would be about 22—up about 40. When running against time, as was the case when the shortest time was made, mentioned in my answer to your second question, the landings down would not be more than two or three, and up they would stop their engines long enough to take a wood or coal flat in tow about three times, *not landing at all.*

4. The higher the water the more time lost in rounding to—about fifteen minutes would be a fair average.

5. The average time out from Port to Port round trip, is about five and a half days. About thirty-three hours lost at Cincinnati, and about eleven hours landing.

6. In low water, the time consumed in the round trip, would not be much greater than that in a "high water trip;" they are longer going down, but lay a shorter time at Cincinnati, and up perhaps from *six to twelve hours* longer than in high water.

7. During the flood of 1847, some of the boats came into Port at Cincinnati and had to lay up, not being able to discharge their cargoes. Others stopped for fear of not being able to get fuel on their route. During the flood of April, 1852, I had to lay over one trip, and lost a week with the "*Allegheny*," (one of the Pittsburgh and Cincinnati packets,) on account of the "Wheeling Bridge"—river being too high to let her Pilot House pass under, after her chimneys were lowered.

8. The ordinary rates of freight in good stages of water up from Cincinnati to Pittsburgh were, last spring, about fifteen cents per 100 pounds, and in very low water twenty-five and thirty cents per 100 lbs.

9. It most assuredly would be advantageous to the steamboat interest to have a full regular supply of good coal for steamboat use at moderate rates always on hand at all points along the river, as the boats here are all so constructed as to burn coal altogether when they can get it.

10. For economy, and quick to generate steam, we think the Pittsburgh coal the best in the western or southern country.

11th Question. How much of each year, on an average, are steamboats laid up on account of low water in the Ohio River?

Answer. This depends somewhat on the season, whether wet or dry; in ordinary seasons the packets were laid up about *three and a half months* on an average, but they are constructed for speed and of heavy draft; we have a class of boats that run the whole summer, or as long as there is twenty inches of water in the channel.

12th Question. Suppose we had a stillwater lake between Pittsburgh and Cincinnati, what would be the probable time required to make the round trip, no current either way? Could it be made quicker than in the natural river on a good stage? How much, probably?

Answer. I think the time required to make a round trip from Pittsburgh to Cincinnati and return by one of our packets on "stillwater," would be about five days. The ordinary time in a business trip I have said in my answer to your fifth question, is about five and a half days, round trip. One-sixth of the difference is saved in not having to round to going down, the balance in having no current to contend with up stream."

C. W. Batchelor.

In a slackwater navigation, as proposed, there would be fifty-four locks between Pittsburgh and Cincinnati. Allowing twelve minutes for each lockage, it would amount to 10¾ hours each way, or 21½ hours in the round trip. Hence, it would appear that even with the natural river in a favorable stage, as compared with the slackwater navigation, the difference of time in a round trip would be trifling; and in low water, that difference would be in favor of the slackwater. There are various other considerations which the intelligent communication of Captain Batchelor cannot fail to suggest to the reader, some of which have been discussed in the text. The equalization and reduction of the cost of freighting which will surely attend the opening of the slackwater navigation, is not the least among them.

While the season of 1856 was remarkably unfavorable for river business on account of long continued low water, causing immense losses to merchants, manufacturers, and others, and curtailing and injuring the coal trade; that of 1857, owing to a better supply of water, has been quite favorable. As a consequence, the commercial and other interests along the river have been in a highly prosperous condition, and the coal business has been greatly stimulated. This extensive business will this year exceed a million of tons, and quite a large proportion of it is now carried on by means of *barges*, even with the river in its natural state; so that what was considered experimental a few years ago, is now an established custom. It needs only a constantly reliable navigation to render it universal.

Appendix E.—Respecting the Improvement of the Mississippi River.

The United States Government has been engaged for several years, in the execution of a plan for improving the lower rapids of the Mississippi.

These rapids are designated as the "Des Moines rapids" or "lower falls." They extend from Montrose to Keokuk, at the extreme southeastern corner of Iowa, and occupy about 12 miles of the river.

The total fall in this distance is 24 feet, or an average of 2 feet per mile—divided between a number of ripples and pools.

The stream is from three-fourths of a mile to one mile in width.

Its bed is solid limestone rock; not in one smooth even declivity, but disposed, as just intimated, into *comparatively* level parts, and intervening broad flat ridges, extending across the stream; partially broken by a very irregular winding channel, which in low water becomes useless.

In very low water, vessels drawing two feet cannot pass. During floods, and generally for about two or sometimes three months of the spring and early summer, steamers drawing four feet, or more, can ascend and descend; and during this period, the immense rafts of timber and lumber from the upper waters, float safely over. But usually, for the remainder of the year, even light steamers are compelled to run the falls empty, while the freight is conveyed by lighters, drawn by horses. Occasionally, of late years, small steam tugs, instead of horses, have been used part of the time.

During the present year (1857), a railroad has been opened along the west bank of the river from Keokuk to Montrose, 11 miles, affording a new conveyance for passengers and freight, *around* the falls. This is the first completed division of the Keokuk, Mount Pleasant, and Muscatine Railroad.

About 10 years ago, a company was incorporated under the laws of Iowa, with authority to construct a *hydraulic ship canal* around the rapids. Surveys, maps, estimates, and reports, were made. Nothing more has yet been done, except to continue the company in being.

The plan adopted by the General Government is, to blow out the rocks under water, so as to form an artificial channel through the flat ridges, sufficiently wide and deep for the convenient passage of steamers and other craft, at all times.

Although several years have elapsed since this work was commenced, and many thousands of dollars have already been expended, very little has yet been accomplished. Nothing that is yet of any practical use. It is evident to those who have had opportunities of witnessing the scene, and the operations, knowing the short period each season during which they can be carried on, that many years of tedious and costly labor will be required to complete a channel on this plan. When completed, the channel would be crooked; and although steamers might ascend it safely, some trouble would be encountered in descending. It is doubtful whether the large rafts could be navigated through it at all.

The effect of cutting such channel, or channels, through the ridges,

(which are in fact rock-dams) must necessarily be, to *reduce the natural depth* in the intervening pools, and on the ridges, and in all parts of the stream, except immediately in the channels. In the channels, the depth must be increased, though not to the full extent of the excavated depth; while, at the same time, the velocity of the flow through the channel will be greater. The worst effect will be, the reduction in the depth of water *above the head of the rapids* at Montrose, and for some distance above. This may prove to be a serious evil, inasmuch as there are shoals on that part of the river which will not admit of any reduction in the depth of water over them without permanent injury to the navigation.

A more philosophical, and the writer thinks, a more feasible and much cheaper plan, admitting of completion in one, or at most two seasons, would augment the depth in the channels, and increase the depth on the shoals immediately above the rapids. Thus, instead of attempting to blow out a channel through the solid rock ridges, let the channel be formed by bolting timbers (on the ridges,) across the stream from either shore; leaving a given width, say 500 feet, near the middle, or in the most convenient part, in its natural state. Suppose three lines of square timber laid side by side bolted to the solid rock; two lines of timber bolted on this lower course; and one line of timber bolted to the second course; we have a solid timber dam, say 3 feet high above the top of each ridge. This would raise the water at each ridge not less than 2 feet—perhaps 2½ feet or more, and afford 4 or 5 feet depth from one end of the rapids to the other, at the same time raising the water at the head of the rapids, not less than two feet above the low water height. Assuming the river to have an average width of 4500 feet, and that there should be eight such semi-dams, it would take 192,000 feet lineal of 12 inch square timber at 30 cents per foot; and allowing 270,000 pounds of wrought bolts, at 15 cents per pound, and twenty per cent. for contingencies, the entire cost would be but $153,720!

Another mode of improving these rapids is, by means of a *single dam*, raising the water 24 feet at the lower end, with two locks of 12 feet each, which is entirely practicable, at a cost of less than a million of dollars!

Ultimately, should the General Government fail to improve these rapids radically; and perhaps in any event, the hydraulic ship canal will be constructed on the Iowa side by the company named, affording one of the most magnificent water powers in the world, and giving a constant reliable navigation. A small portion of the surplus water will be used in supplying the growing City of Keokuk with pure wholesome water. Is there any good reason why the government should not construct this canal?

ERRATA.

Page 6, line 16—for "*cleaning*" read "*clearing*."
21, " 15—for "*high*" read "*height*."
23, last line for "*draughts*" read *droughts*.'
25, line 17—for "*draught*" read *drought*."
25, " 20—for "*foot*" read "*feet*."
29, " 22—the semicolon should be a colon.

(2)

IMPROVEMENT OF THE OHIO RIVER.

REVIEW OF THE PRACTICAL VIEWS

OF

W. MILNOR ROBERTS, Esq., Civ. Eng.

BY

ELLWOOD MORRIS, C. E.

IMPROVEMENT OF THE OHIO RIVER.

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BY

ELLWOOD MORRIS, Civ. Eng.

The public are indebted to W. Milnor Roberts, Esq., (a Civil Engineer of great experience and reputation,) for a long and valuable contribution to the discussion of plans *for the improvement of the Ohio River*, which is published in the *Journal of the Franklin Institute*, for 1857.

This skilful engineer, with great apparent fairness, reviews the three leading plans proposed for the attainment of this great national object, (1. Reservoirs; 2. Low open Dams; 3. Slackwater Navigation;) but being himself *the special advocate of the system of locks and dams alone*,* this fact probably leads him to look with less favor upon the others, and possibly even to exaggerate their difficulties.

The writer, on the other hand, frankly avows, that having closely studied this subject, and being personally familiar with the Ohio River, he has become strongly impressed with the vast superiority of the system of reservoirs proposed by Charles Ellet, Jr., Esq., C. E., and fully satisfied that an accurate survey alone, is all that is necessary to find adequate sites for reservoirs, and to demonstrate both the practicability of the plan, and its pre-eminence over all others.

No discussion will obviate the necessity of a suitable survey,—no artificial obstructions in the Ohio River will be tolerated by the people until such survey is made—and the writer being convinced that a survey alone, will decide the question without further argument, in favor of the reservoir plan, desires in this place (by permission of Mr. Roberts, very politely accorded,) merely to review briefly a few of the cardinal errors (apparently such,) into which it would appear (in the judgment of the writer,) that this distinguished engineer has inadvertently fallen.

These apparent errors in the essay of Mr. Roberts, are as follows, *to wit:*

Relating to the Reservoir Plan.

1. *In assuming* in advance of a survey, a definite number of artificial lakes, in arguing the practicability of the reservoir plan, on that assumption, and that the cost would be increased with a number of smaller reservoirs.

* See Reply to Mr. Ellet. Jour. Frank. Instit., Nov. 1857, p. 354.

2. *In assuming* the available annual rain-fall at 12 inches only, instead of 18 inches or more, to which all modern experience points.

3. *In understating* the probable contents of reservoirs located on favorable sites, with dams 100 feet high.

4. *In overstating* the probable cost of reservoirs necessary to contain 150,000 millions of cubic feet of water.

5. *In assuming* upon meagre and inadequate data to determine the position, content, and practicability of the necessary reservoirs, without a special survey in each case, which can alone decide such questions.

6. *In contending* that reservoirs or artificial lakes may render the neighboring country unhealthy.

7. *In assuming* that no allowance has been made for evaporation between the reservoir sites and the Ohio River, when in fact 20 per cent. has been allowed.

Relating to Low Open Dams.

1. *In assuming* that 75 wing dams, each of 5 feet lift, having 200 feet open way in the centre, "with pools averaging 10½ miles in length," would maintain a 6 feet navigation with any less supply of water than the unobstructed river would require.

2. *In supposing* it possible that a river may have for 10 miles a central current 200 feet wide with 2 miles per hour velocity, and on each side a littoral current with only ½ mile per hour velocity.

Relating to the System of Locks and Dams.

1. *In taking for granted* that a slackwater navigation upon the Ohio, with double locks of proper size, could be maintained 6 feet deep, at all seasons, without aid from reservoirs.

2. *In assuming* that the construction of numerous dams of 8 feet lift each, with pools of a minimum depth of 6 feet, will not very seriously augment the height of the floods of the Ohio.

3. *In assuming* that the formation of 50 slackwater pools in succession, destitute of current, or nearly so, in low water, will not largely increase the delays and obstructions produced by ice.

4. *In understating* the probable cost of constructing a system of locks and dams on the Ohio River.

5. *In understating* the propable annual cost of repairs, renewals, and attendance of a lock and dam navigation, 975 miles long.

6. *In assuming* inadequate dimensions for the locks proposed.

7. *In assuming* that the locks of a slackwater likely to be choked with trade, could be allowed to be used as wharves for the reception and delivery of freight, or as passenger stations.

Other fundamental errors or inadvertencies (the writer believes,) could easily be pointed out in the otherwise able and interesting essay of Mr. Roberts, but he will confine himself for the present to the discussion of these *sixteen radical errors* alone, in the order of their places and numbers as above set out.

Relating to the Reservoir Plan.

1. The writer, in a former communication, criticised by Mr. Roberts, assumed in advance of a survey, *as the most unfavorable view* of the reservoir plan, that *six* great artificial lakes would be required—but in anticipation of an argument like that under review, he looked forward also to the probability of using "a greater number of lakes of equal aggregate capacity."

Mr. Roberts in his elaborately detailed argument, has strengthened the opinion that the most unfavorable view was taken by the writer in limiting the number of artificial lakes to *six*, in framing an estimate of cost; but he has not brought forward *a particle of evidence* to show that a greater number "of equal aggregate capacity," may not fully answer the intended purpose.

For Mr. Roberts's references to the small reserviors used to feed the summits of little canals, located as they necessarily are, on very unfavorable sites—on sites which Mr. Roberts knows would never be selected by any engineer, as locations for those the Ohio River will require, is not only furnishing *no evidence*, but is approaching to the verge of a disingenuous argument.

With *six* artificial lakes only, it was necessary to provide for a water raise of at least 100 feet, and for a great mass of cemented masonry to retain and protect the embankment of such large structures—this masonry alone was estimated at $800,000 *for each dam!*

Now, if we employ a greater number of reservoirs of "equal aggregate capacity," the dams become *lower* as well as more numerous, the masonry may be dispensed with, and the total cost of the greater number of smaller dams becomes less than has been assumed by the writer, *or less than* $12,000,000 *for all.*

This question of cost is evidently the only important one in this connexion, as within reasonable limits; it matters little how many reservoirs we employ, so that the necessary cubical content is secured, and the cost not enhanced.

2. Mr. Roberts in questioning the very liberal estimate of the writer ($12,000,000 for the reservoir plan), first arbitrarily reduces the available downfall of rain, against all experience; and secondly, contrary to the result of analogous surveys, assumes that the content of the lakes proposed by the writer will be much reduced in execution.

In this summary manner he increases largely the number of reservoir lakes required, and swells the reservoir estimates to perfectly preposterous proportions.

The writer, however, has taken no step in this grave investigation, without due authority to rest upon, and will now produce unquestionable evidence to dispel these erroneous assumptions; admitting at the same time, that these are to a great extent questions of fact, which suitable surveys alone can settle beyond dispute.

Up to about the year 1840, when the rapid advance of railroads

1*

brought to a stand the construction of canals, the engineers of this and other countries were in the habit of assuming only from ⅓d to ⅜ths of the annual rain-fall on any given site, as the quantity available in reservoirs, and beyond this point Mr. Roberts does not appear even yet to have advanced, for in the face of a vast amount of evidence to the contrary, he assumes, "that it is not safe in this latitude to count on saving or utilizing more than 33⅓ per cent. of the annual downfall of rain and snow!"

But all modern experience indicates a much higher ratio of available rain-fall annually collectable in reservoirs.

The growth of the large towns of Great Britain, and the inadequacy of the old methods of water supply in many of them, has led to the most minute and accurate examinations of the quantity and ratio of annual rain-fall available in reservoirs, from the drainage of gathering grounds of known area; and these examinations have resulted in demonstrating that a very large proportion of the annual rain-fall—far exceeding *one-half* in many instances—is collectable in reservoirs even from flat and cultivated sites!

This great fact, *that more than half the annual downfall of rain* is always collectable from ordinarily impervious gathering grounds, has been proven not only by elaborate surveys, but by the actual construction and successful working for years of many important gravitation water works in Great Britain, with the results of which every civil engineer is, or ought to be, acquainted.

In every instance of European experience in the drainage to reservoirs situated in the coal measures—as will be all that may be placed on the heads of the Ohio River—*the available annual rain-fall has exceeded one-half of its vertical depth by the gauge, and has never been less than two feet!*

It is not possible here, even to notice the great mass of experience, on this subject of available rain-fall, which seems to have been entirely overlooked by Mr. Roberts—but the writer to sustain his own view, *that fully one-half of the annual rain-fall is collectable from reservoirs located on the coal measures*, will briefly refer to a few instances.

The two reservoirs supplying the summit level of the Peak Forest Canal, in Derbyshire, contain 101,701,270 cubic feet, and drain 11 square miles of gathering ground; they use *only* the flood waters, the ordinary flow passing regularly to the mills below. One of them, erected more than half a century since, has never failed to fill from the *surplus* of floods alone. In dry years the annual rain-fall is 33 inches, and it is found they always collect 24 inches vertical from the whole surface of their gathering grounds, *or seventy-two per cent!*

The Corporation of Manchester has constructed several reservoirs containing 600 millions of cubic feet of water, and draining an area of 29 square miles. They have bound themselves to furnish the mill owners below, an annual quantity equal to 31 vertical inches of the rain-fall upon the gathering ground—*besides supplying the wants of the City of Manchester!**

* Homersham's Report. Journal Soc. of Arts, London, 1855.

At the Paisley Water Works, experience has shown, that from 54 inches of annual rain-fall, 36 inches accumulates in the reservoir, *or sixty-six per cent.* This case is peculiar, as Mr. Thom, the well known hydraulic engineer, who finally executed the works, pronounced the scheme at first *impracticable*, and declared that not over 18 inches vertical, *or thirty-three per cent.*, of the rain-fall was collectable—agreeing here precisely *in opinion* with Mr. Roberts, and demonstrating after by the successful execution of the works, *his own error.*

This shows the danger of engineers being over-cautious against facts, and is doubly applicable to parties hostile to a plan, whose wishes are father to their thoughts.

At Greenock, Shaw's Water Works, from an annual rain-fall of 65 inches, 42 inches vertical, *or sixty-four per cent.*, is found to be available in the reservoirs.

Another point of consequence has been determined in recent reservoir experience, in Scotland, *viz: that no aquatic plants grow where the water is over 12 feet deep.**

In deep reservoirs, therefore, there can be no decaying vegetable matter to affect the public health.

The experience of the Schuylkill Navigation, extending over many years' actual use of reservoirs in a coal region, and the writer having become satisfied from his own experience whilst in the service of that Company, that more than 18 inches vertical of the rain-fall was annually collectable from the gathering grounds of their 3 reservoirs—made inquiry recently of James F. Smith, Esq., their present Chief Engineer, and learns from that gentleman, that, "from several years' observation (on the Silver Creek reservoir,) during very variable seasons, it has been noticed that in from four to six weeks after the closing of the stops (about February 1st each year), the reservoir fills up from melting snows and a moderate amount of rain. The time of filling has never exceeded two months, in which space a quantity of water equal to 13 vertical inches on the drainage surface is secured, leaving the early and the latter rains of Summer to run to waste or to replenish the reservoir."

And this experienced canal engineer concludes by expressing his conviction that from reservoir sites, analogous to those upon the Schuylkill, "18 *inches of the rain-fall could be relied upon for reservoir purposes.*"

Now the experience of the writer with these reservoirs, added to that of Mr. Smith, extends over a continuous space of *twelve years*, with one uniform result, and surely ought to be of some value as a point to reason from in similar cases.

But the testimony showing that *more than half the rain-fall is collectable*, is so redundant that it seems needless to farther elaborate it, and we will now add a table compiled from Hughes on Water Works, Beardmore, McAlpine's Reports, and other sources, thus grouping a portion of the authorities on which we rely, amongst whom is Mr.

* Stirratt on the Gathering Grounds of Scotland. C. E. and A. Journal, vol. xiv, p. 92.

Roberts himself, when communicating information to a brother engineer (Major Gwynn,) and not merely maintaining a thesis.

Table of Rain-fall annually, collectable from Gathering Grounds.

No.	NAME OF DRAINAGE AREA.	Annual rain-fall in inches.	Drainage flowing away in inches.	Ratio, or pr cent. of the rain which drains off.	AUTHORITIES.
1	Bann Reservoirs (moorland),	72	48	66	Beardmore and Hughes.
2	Greenock (flat moor),	60	41	68	
3	Bate (low country),	45	24	53	
4	Glencoose (Pentland hills),	37	22	60	
5	Belmont (moorland), 1843,	63	51	80.	
6	" " 1844,	50	33	67	
7	" " 1845,	55	41	75	
8	" " 1846,	50	33	67	
9	Rivington Pike, (Liverpool works,)	55	24	44	
10	Paisley Water Works,	54	36	66	Stirratt.
11	Glasgow " "	50	30	60	C. E. and A. Journal.
12	Rivington Pike in 1847 and 1848,	64	40	63	Hughes.
13	Turton and Entwistle, 1836,	46	41	89	
14	" " 1837,	48	39	81	
15	Greenock, Shaw's Water Works,	65	42	64	Stirratt.
16	Peak Forest Summit,	33	24	72	Homersham.
17	Ashton,	40	15	39	Hughes.
18	Longendale in 1845,	60	40	66	Bateman.
19	Schuylkill Navigation Reservoirs,	36	18	50	Morris & Smith.
20	Eaton Brook,	34	23	66	McAlpine.
21	Madison Brook,	35	18	50	
22	Patroon's Creek,	46	25	55	
23	" "	42	18	42	
24	Long Pond,	40	18	44	Boston Wat. Comrs.
25	West Fork Reservoir,	36	14	40	W. Milnor Roberts.
	Totals,	1216	758	1527	Various authorities in England and America.
	Averages,	48	30	62	

These 25 examples show an average rain-fall per annum of 48 vertical inches, and an annual amount collectable in reservoirs of 30 inches, *or sixty-two per cent.*

If authority and experience are worth anything, surely there is enough before us here, to justify the most cautious engineer in assuming, *that half the rain-fall is collectable in reservoirs.*

What that rain-fall is upon the heads of the Ohio, we have ample evidence in "Blodget's Climatology," (J. B. Lippincott & Co., Philadelphia, 1857,) from the elaborate tables of rain-fall in that valuable work, and from the Hyetal or Rain-chart of the United States (p. 354), it is quite clear, that we may safely count upon 36 inches of annual rain-fall on the head waters of the Ohio River.

Again, W. Milnor Roberts, Esq., C. E., in his letter to Major Gwynn, says:—"My own estimate of the annual fall of rain in Pennsylvania and

Ohio, for *practical calculations*, has always been 36 inches, though in fact it is probably a few inches more."*

This valuable extract shows the opinion of a skilful engineer, then engaged in the construction of reservoirs, and not in composing "*Practical Views*" to condemn them.

The rain-fall upon any site being determined, it is only necessary to ascertain correctly, *the ratio draining away* for a year or two, and it will be found that this *ratio* will proximately apply to any annual rain-fall on such site.

Now the rain-fall on the sources of the Ohio being 36 inches vertical, and the average ratio of drainage in the 25 cases quoted being 62 per cent., the writer would be justified in assuming 22 inches as being *available.*

For perfect safety, however, he assumes *eighteen inches vertical, or fifty per cent., of the rain-fall as collectable in the proposed Ohio River reservoirs.*

Even if we admit that once in a dozen years we may only be able to collect 12 inches of the downfall, the result would be that for such year, we would have only *a five feet navigation,* instead of 6 feet, and the extra reservoir capacity would go to moderate the violence of floods.

3. Without advancing any evidence, Mr. Roberts arbitrarily assumes that the mean depth of reservoirs will rarely exceed "one-third of the greatest depth," and that therefore the writer in assuming *one-half* the water raise, as the mean depth of the reservoir pools, "has largely overestimated the actual capacity."

While it is beyond doubt that in this particular, great variations would be shown by surveys of different sites, the writer submits below a table of 15 reservoirs which have been accurately surveyed, and in which the average mean depth is precisely *one-half of the water raise at the dam.*

This position, then, was not lightly taken by the writer, and it will require something more than the mere declaration of Mr. Roberts to overturn it, in the face of the facts stated in the subjoined table, which show the laxity of his reasoning upon such points.

The mean depth here referred to, is found in all cases by dividing the cubical contents of each reservoir, by the surveyed area of the pool.

* James River and Kanawha, Fifteenth Annual Report, p 35.

Table showing the ratio of the Mean Depth to the depth at the Dam, in fifteen different Reservoirs surveyed.

No.	NAME OF RESERVOIR SURVEYED.	Water raise at dam.	Mean depth.	Ratio of mean depth to water raise.	AUTHORITY.
		In vertical ft.		per ct.	
1	Gillies,	48	30·1	·627	Surveys of Col. J. J. Abert, Chf. Top. Engrs. U. S.
2	Warners,	38	25·4	·667	
3	Beaver,	40	25·3	·633	
4	Cabin,	30	20·1	·670	
5	Patuxent,	42	28·0	·666	
6	Seneca,	40	17·0	·425	
7	Goshen,	20	13·6	·680	
8	Hawlings,	45	16·3	·367	
9	Patuxent,	50	20·3	·406	
10	Cattail,	40	14·1	·352	
11	Big Branch,	30	14·0	·466	
12	Big Creek,	80	22·0	·275	Surveys of Ellwood Morris.
13	*Silver Creek,	37	17·0	·460	
14	Wolf Creek,	59	24·0	·400	
15	Isenhote's Run,	35	15·0	·430	
	Fifteen reservoirs,			7·524	

Average mean depth precisely 50 per cent. of the greatest depth or water raise at the dam.

It may also be observed, that in the most recent extensive reservoir surveys—those on the summit of the James River and Kanawha Canal, the locating engineer, E. Lorraine, Esq., assumes the mean depth of each of his surveyed reservoirs at *one-half* the depth at the dam.†

4. In estimating the probable cost of reservoirs for the Ohio, Mr. Roberts takes for *his unit* the Conemaugh reservoir, and assumes that the cost of collecting 150,000 millions of cubic feet of water will be $53,410,000! Astonished apparently at this preposterous result, he liberally throws off *one-half*, and adopts for his estimate $26,705,000!

Now every engineer knows that from the high level of canal summits, and the small extent of drainage ground which usually lies above them, we are almost invariably compelled to select unfavorable sites for reservoirs to feed them. We are necessarily limited in our choice of ground, and the writer could furnish to Mr. Roberts the details of a constructed reservoir *as a unit*, from which he might have computed the cost of those required for the Ohio River at $100,000,000! *But are such estimates of any value? Is this a fair mode of reasoning?* With such a vast scope of country to select from as that drained by the heads of the Ohio, would any engineer select such unfavorable sites?

* Constructed by the Schuylkill Navigation Company, in 1848, under the direction of the writer.

† James River and Kanawha Co., Sixteenth Annual Report, p. 402.

The only large reservoir lately located with accuracy, which in any degree compares with those which are likely to be employed for the Ohio River, is the Anthony's Creek reservoir, in Virginia, of which a sketch is given at fig. 3.

Thirty feet of the top of this reservoir pool contains 2948 millions of cubic feet of water, and the whole pool at least 4000 millions.

The total cost of this reservoir would have been less than $250,000, and as about 40 of them would be needed to collect 150,000 millions of cubic feet of water, the whole cost deduced from *this unit* would be but $10,000,000, whilst the writer, in his own liberal estimate, has allowed $12,000,000.

If, then, we adopt this mode of estimation at all, the writer submits that the Anthony's Creek reservoir would be a much more suitable unit than that assumed by Mr. Roberts; but he repeats again, that all these questions are legitimately to be decided *by surveys alone, conducted specially for the object in view.*

5. The information supplied by Mr. Roberts in relation to the Allegheny and its tributaries especially, is derived mainly from experimental lines traced with reference *to railways*, and though very creditable to his research and topographical knowledge, is yet entirely inadequate to decide the availability of those streams for reservoir purposes, since reservoir surveys are conducted upon entirely different principles, and would doubtless discover sites upon these very streams that would surprise even Mr. Roberts himself. Upon many of them good sites unquestionably exist for numerous reservoirs of less magnitude than have hitherto been contemplated by the writer, and the engineer who may be charged with the surveys, will doubtless avail himself of the valuable data furnished by Mr. Roberts, to avoid *the impracticable sites* he discusses so elaborately—*but which no one would adopt.*

6. On the subject of *health*, the writer will only refer to two cases, both well known to Mr. Roberts, but passed unnoticed by him.

Two of the reservoirs of the Schuylkill Navigation (on Tumbling Run, Schuylkill Co., Pa.), are in sight of the Mount Carbon Hotel, a well known and favorite resort for persons seeking to renovate their health, and a place celebrated for its uncommon salubrity.

These reservoirs (it is well known), though in use for years, have produced no unfavorable influence upon the public health. But they are both deep, and aquatic plants do not grow in them.

The writer will now cite another case which he must confess has often surprised himself. It is that of *the Quitapahilla Reservoir*, of the Union Canal, near the town of Lebanon, in Pennsylvania.

This is a shallow pond, from which the water is pumped into the Union Canal; it is located in a rich limestone valley, *and is filled with aquatic plants.*

In the Summer season, when this pond is pumped down (as usual), the heated and festering vegetation emits an odor, almost overwhelming to a stranger, *yet the health of the country is not at all affected!*

Here is a most striking case, and we think this with other results prove

beyond doubt, that no danger to the public health need be apprehended from the construction of deep and extended reservoirs of pure water, upon the heads of the Allegheny and Monongahela Rivers, or their tributaries.

7. The probable amount of water needed for the maintenance of 6 feet navigation in the Ohio River, deduced from the driest year of which we have the records at command, is 126,000 millions of cubic feet;—while the quantity used in the calculations of the writer is 150,000 millions—the difference, *twenty per cent.*, being allowed for loss between the reservoirs and the head of the Ohio—so that this point has *not* been neglected, as Mr. Roberts assumes.

Relating to Low Open Dams.

1. Mr. Roberts proposes to amend Mr. Haupt's plan, by dispensing with the long and narrow chute, (necessary to maintain a depth of 6 feet with *a diminished quantity of water*,) and forming a system of low dams of 5 feet lift each, these dams being merely wings run out from each shore, and leaving between them a vacancy or open-way of 200 feet —*being discontinuous weirs in fact*, separated by an opening 200 feet wide, without prolonged side walls.

The apparent object of this singular plan of Mr. Roberts, is to form a 6 feet navigation, *with only one-third of the water that the unobstructed river would require*, by means of a series of such low open dams placed about 10 miles apart, on an average.

Now to augment materially the depth of a river with a small quantity of water (inadequate to the object in the original channel), it is so evident that the section of the channel must be uniformly reduced or contracted laterally—that it is almost inconceivable how a skilful engineer like Mr. Roberts, could have brought forward such a proposition, especially after investigating the plan of Mr. Haupt, which is theoretically correct, and recognises the established hydraulic principle, that a river in permanent flow must have *a fixed regimen*, or a determinate slope, and a limited section.*

The writer more than once has had to direct the operations for closing accidental breaches in dams opening upon the pools of others, which presented, at the breach, in effect, one of Mr. Roberts's *open dams*, and he has had occasion to notice that the level of the water below, within a quarter of a mile, was *unaffected* by the flood pouring through the *open dam!—How then could its effect extend* 10 *miles?*

Fortunately, however, this is a simple problem in hydraulics, which may be despatched in a brief space.

By the well known formula for *discontinuous weirs*,

$$Q = \cdot 90\, b \sqrt{2\, g\, h}\, (\tfrac{2}{3}\, h + a),$$

the quantity of water expended by a dam of 5 feet lift through an open-

* It seems truly extraordinary, that Mr. Roberts, after proposing this improvement of Mr. Haupt's plan, and devoting seven pages to its discussion, should have subsequently avowed (*Jour. Frank. Instit., Nov.*, 1857, *p.* 354-5,) that he is utterly opposed both to Mr. Haupt's plan, *and to his own improvement!*

ing 200 feet wide and 10 feet deep, issuing upon a pool below, would be 2,319,840,000 cubic feet in 24 hours, or enough to maintain an uniform depth in the Ohio River of about 9 feet!

On the other hand, an opening in a dam of 5 feet lift, wide enough to deliver the quantity of water necessary to maintain a uniform navigation 6 feet deep, would have a width of less than 100 feet! And if just wide enough to pass the quantity of water allowed by Mr. Roberts, would be *too narrow* for the passage of an ordinary steamboat! Such would be the result of any attempt to maintain *a six feet navigation* by open dams " of 5 feet lift from pool to pool," forming a species of *slackwater*—but since composing the above, the writer (much to his surprise,) has learned from Mr. Roberts, that in this scheme of " low open dams," it was not his intention to propose the complete six feet navigation (which by common consent has been taken as a basis in this discussion), but merely to elevate the summits of his " low dams " 5 feet above low water, thus making the depth, say, only 6 feet immediately at such dam, and gradually diminishing upstream, through the pool (so-called) to the low water limit of only *one foot deep*, at the base of the next dam above!

Upon this singular plan, the idea seems to be, that a small amount of water, pouring through the 200 feet openings, would by a sort of freshet action, or some peculiar necromancy unknown to the engineering profession, float loaded steamboats &c., *over the one foot shallows* at the head of every pool, until a deeper excavation of the river bed, or the immediate vicinity of the next dam should give a floatation *six feet deep!!*

In this strange form, there seems no doubt whatever that Mr. Roberts's peculiar " low dams with open ways " will require a vast deal more water *for a six feet navigation* than he anticipates, and as he appears himself to have abandoned the plan, or ceased to advocate it,* we also may dismiss it by stating, that Mr. Roberts's amendment to Mr. Haupt's plan is *no improvement;* in fact, in the form now stated, and for the purpose of maintaining a 6 feet navigation, *it is utterly impracticable without the expenditure of nearly as much water as the unobstructed river would require!*

2. In connexion with his peculiar proposition for low open dams (of which, however, he is not even himself the advocate*), Mr. Roberts suggests the practicability of a river having a rapid centre, and slow side currents, differing in velocity so much as 1½ miles per hour! But a little calculation would show that it is not possible for such currents to exist in the same river, at the same time, for any considerable length of its course, and it is therefore useless to discuss this idea.

Relating to a System of Locks and Dams.

1. The first question here is the lifts of the dams and the size of the locks—the former has been fixed by Mr. Roberts at 8 feet each, and for the proper dimensions of the latter, so as " fully and adequately to accommodate the navigation," we cannot do better than consult the

* Journal Frank. Inst., November, 1857, p. 354.

Report of the able Commission of Engineers, appointed by the Government some years since, to examine the Louisville Canal.

This Commission, (Col. Long, Major W. Turnbull, and C. B. Fisk, Esq., C. E.,) whose words we quote, fixed upon 420 by 80 feet as the proper size for locks to accommodate "*fully and adequately*" the trade of the Ohio River.*

The next question in this connexion is—*what is the low water flow of the Ohio River?*

Mr. Roberts quotes gauges by Capt. Sanders, to the effect that the Allegheny flows 150,000 cubic feet per minute, and by gauges of his own, that the Monongahela furnished at low water 12,000 cubic feet per minute (though this he subsequently modified).

Upon this *assumed* low water flow of the two rivers forming the Ohio, Mr. Roberts bases many pages of arguments, which, as they depend entirely upon this *assumed flow*, fall in a body, if in that there is an error.

Now the writer has searched in vain for the estimate ascribed to Capt. Sanders, of the Engineers; on the contrary, in two public documents† containing the reports of that officer, he finds the following as the result of extreme low water in 1838:

Allegheny River, flow per minute,	=	80,000	cubic feet.
Monongahela, " " .	=	20,000	" "
Ohio River, " " .	=	100,000	" "

Before this statement, falls a large portion of Mr. Roberts's reasoning, which it is not necessary to specify.

It is difficult to fix upon a precise quantity for the low water flow of the Ohio, but we may probably assume for the Allegheny the 80,000 cubic feet named by Capt. Sanders, and add the 4500 feet stated by Mr. Roberts in his Appendix—*say, in all,* 84,500 *cubic feet per minute for the low water flow of the Ohio,* which is more than Mr. Ellet makes it, by gauging at Wheeling.

Now with the press of trade which may be expected on such a navigation as that under consideration, it is not too much to estimate that the double locks will br may be worked to their maximum limits of passage, and Mr. Roberts informs us on good authority, that the time of *one* lockage is *six minutes*, though he himself assumes *five*.

As we know that the leakage and evaporation frequently "*dries up*" the pools of the Monongahela navigation, and that the whole Summer flow of that considerable river, is sometimes lost chiefly by the leakage of the dams, leaving us in doubt how much more would leak if the stream had supplied it; bearing in mind, too, that the dams proposed upon the Ohio would be much longer, we can hardly doubt that Mr. Roberts's gauged quantity of 12,000 cubic feet per minute would be more than absorbed by the sources of loss which seem inseparable from slack-water navigation; and it appears to us that at a very moderate calculation

* Ex. Doc.: No. 42, 32d Cong., 2d Session, (Senate.)

† House Doc., No. 50, 27th Congress. House Doc., No. 2, 25th Congress.

we may assume 20,000 cubic feet per minute as a measure of the probable loss from the Ohio River pools, *exclusive of lockage.*

Upon this supposition, the fairness of which the writer freely submits to the reader of these discussions, we shall have available for use as *lockage water* only 84,500—20,000=64,500 cubic feet per minute.

Now at *six minutes* each, we shall have 240 lockages in 24 hours, or for *both* locks say 480 lockages per day.

But there are circumstances to be taken into account, which practically increase the lifts of locks in dams—thus a strong wind down stream will often raise the water above the locks nearly a foot, wasting large quantities over the dams, and also depressing as much, the lower level.

In this manner the lifts may be practically increased to about 10 feet, and as we make no special allowance for leakage at the gates, or imperfections in the locks, it is necessary for "*practical calculations*" to assume a margin in the lifts—*let us take them at ten feet.*

We have then required for lockage per day =420×80×10×2×240, .	=	161,280,000 cubic feet.
Daily available low water flow of the Ohio 64,500×60×24,	=	92,880,000 " "
Daily deficiency in low water to be supplied by *reservoirs !*	=	68,400,000 " "

So that the probabilities are strong, that a slackwater navigation of proper dimensions upon the Ohio River if actively worked, *would require the aid of reservoirs,* and this is the experience on other rivers.

2. The extent to which the rise of floods will be augmented by the obstructed flow caused by placing dams in the Ohio River, is a question of great importance, and in a practical way of easy solution.

It is admitted by Mr. Roberts, and all the authority he quotes (Messrs. Copley, Welsh, and Lothrop), and is confirmed by the profiles of the floods in the Potomac River, furnished by the writer, that a 16 feet freshet over 8 feet dams, will give approximately a depth upon the combs or summits of those dams of about 8 feet, practically drowning them out, or restoring very nearly (though not exactly) an inclined plane parallel to the natural descent of the river.

Now although, owing to the impeded flow, a slight wave or elevation would still be noticeable over each dam, we may in the first instance for the sake of simplicity in the argument, assume, that a 16 feet flood would actually form an inclined plane over the dams (see *p p* fig. 2).

This line, it will upon examination be observed, is *actually higher* than it would have been in the unobstructed river, *by precisely the proposed minimum low water depth to be added by the pools, or five feet.*

Tho top water surface of a 16 feet freshet on the slackwater navigation, would therefore *coincide with that of a 21 feet freshet in the unobstructed river.*

Or in other words, the rise of a 16 feet freshet would unquestionably be augmented by the dams *about five feet !*

Now this underline, or inclined plane of a 16 feet freshet, being once formed 5 feet higher in consequence of the dams, would bear up all superimposed water, and would of course produce *at least the same extra elevation in all higher freshets.*

But a long wave easily traceable by the engineer's level, (though probably not so by the eye unaided,) will naturally form over the summit of each dam in all freshets; ice will also gorge, where local circumstances favor it, and hence the writer concludes that it would not be safe to expect a less augmented rise of floods as consequent upon the proposed slackwater *than from five to nine feet.*

And he begs to refer to figs. 1 and 2, in further illustration of this interesting and important question.

So great an augmentation of the floods of the Ohio, as 5 to 9 feet! which our reasoning leads us to believe not only probable, but positively certain, seems to the writer to be *entirely inadmissible* for the Ohio River, as it would involve *the destruction* of too large an amount of very valuable, town and country, property, for any improvement to justify—the risk would be too great for the object.

3. Common observation teaches us, that in cold weather shallow ponds freeze first, mill dams next, and running waters last, and these are "*practical views.*"

It follows, then, as a dictate of common sense, that as between an unobstructed river with a uniform current flowing away not less than six feet deep, and the same river converted by numerous dams into many shallow pools of slackwater, that those pools would unquestionably sooner congeal, and longer continue frozen, than the open water of the running river would.

Experience, (of course,) on all rivers sustains this view, and we find that during last winter alone, the Monongahela navigation (though a southern stream) *was ice bound for three months!*

The effect of ice on slackwater pools even when *very deep*, is strikingly shown every spring upon the Union Canal, of Pennsylvania, where, contrary to Mr. Roberts's arguments, the shallow canal is always open and navigable some weeks before *the ice* upon the "Big Dam" (a deep pool on the Swatara,) will allow of the passage of boats.

In fact, before we could concede, that shallow slackwater pools can remain unobstructed by ice, we must all unlearn the teachings of experience; while on the other hand, none of us can doubt that a running river at least six feet deep, will be but rarely troubled by the congelation of its waters.

4. It would be an easy matter to criticise the details of the estimate offered by Mr. Roberts for the cost of locks and dams, but the writer does not conceive that any good result could flow from such a train of reasoning, and prefers to rely on the general views suggested by *two* analogous cases, one of them much relied upon by Mr. Roberts.

The Kentucky River navigation consists of five locks and dams:—the former are single and of small dimensions, whilst the latter are only about one-third of the length of those required for the Ohio—yet this navigation cost $1,000,000—each single lock and dam, small as they are in comparison with those destined for the Ohio, having cost $200,-

000, or about the same as Mr. Roberts's estimates for double locks of *twice* the size, with dams *three times* as long!

Surely there must be an error in such estimates as his.

In the opinion of the writer, double locks of *twice* the size of those of the Kentucky navigation, placed in dams of *thrice* the length, and subject to much more formidable freshets, could not fairly be estimated at the present day at less than $500,000 each; and at this rate a slackwater navigation of the Ohio River would cost at the least $500,000 ×50=$25,000,000!

In like manner the Monongahela navigation with its four small locks (two of them double), and four dams, small in comparison with those required for the Ohio, has cost about $700,000. Adding to this for double locks throughout, and the necessarily increased lengths of the dams, and it seems not unfair to infer from the experience of this navigation, that the cost of a slackwater upon the Ohio would swell up to about $20,000,000,—*at the least.*

Minute data, not now possessed, are of course necessary to accurate estimates, but the writer offers these with some confidence as probable inferences, from the known cost of existing works, erected for use, and not merely to sustain an argument.

5. In the maintenance of canals and slackwater navigations, it is usual to allot a foreman and scow gang to every 5 or 10 miles, (making about one man to a mile,) while Mr. Roberts in his estimate for the maintenance of an Ohio River navigation, allows but one scow gang to 100 miles, *or one man to ten miles!*

The Schuylkill navigation, 108 miles long, of which a large portion is slackwater, cost on the average of many years $1000 per mile for annual repairs; yet Mr. Roberts has ventured to estimate the maintenance of an Ohio navigation at only $100 per mile, or about *one-tenth!*

Nor has Mr. Roberts made the least allowance for *renewals*, and yet both dams and locks *are perishable.*

The experience of the Schuylkill navigation leads to the conclusion that a large portion of every dam and lock *requires renewal about every twenty years.*

At this rate the average annual renewals alone upon the work estimated by Mr. Roberts, will amount to nearly a half million of dollars per annum! *instead of nothing, as he estimates!*

Without going into details on this point, it is quite clear that the small sum of $107,000, estimated by Mr. Roberts for the annual maintenance of a slackwater on the Ohio, is *entirely inadequate;* and from the experience of the writer, even half a million would be insufficient.

6. It is of the greatest importance that the dimensions of the locks of a river navigation should be ample—in all such cases experience shows us that the tendency is to select *too small dimensions:* at this very moment great trouble is produced by the insufficient size of the

locks at the Falls of the Ohio, although at the time they were built, their dimensions were deemed ample.

The steamboats in use upon the Ohio vary much in size, but the *Magnolia*, and others of her class, are 295 feet long, and 72 feet beam.

For boats of this class to pass freely, a lock must be at least 300 feet long, *clear of the swing of the gates*, and 75 feet wide, so that the dimensions fixed by the very able governmental Commission upon the Louisville Canal, (Col. Long, Maj. Turnbull, and Charles B. Fisk, Esq., C. E.,) *to wit:* 420 feet by 80 in the chamber, are the very least that should be thought of for a navigation of the magnitude of that under consideration.

We think, therefore, that nearly all the Ohio River men will agree with the writer, that the lock dimensions assumed by Mr. Roberts, *viz:* 350 feet by 60 in the chamber, *are totally inadequate for the object.*

7. Mr. Roberts has advanced the idea that the locks of an Ohio slackwater, may be used as docks or wharves for the reception and delivery of *freight*, and also as *passenger* stations—but any such disposition of them could only take place on a navigation of very limited business, and would be entirely incompatible with the regular transit of an annual business of "not less than three hundred millions" in value, passing by a continuous series of lockages at intervals of 5 or 6 minutes apart.

No such use of locks is now permitted in this country, upon any of our navigations transacting *a heavy business*, nor can any material advantage ever be hoped for from this part of the scheme of Mr. Roberts.

Concluding Observations.

One advantage at least appears to have been already realized by the discussion of the Ohio River improvement, *viz:* that the plans most worthy of attention have been reduced to *two*—1. *Reservoirs.* 2. *Slackwater.*

The reservoir improvement carries with it of necessity as collateral, an improvement also of the main tributaries, on the heads of which the artificial lakes may be established, *and it proposes no obstructions whatever in the channel of the main river.*

The slackwater plan, on the contrary, as its first step, *proposes to establish* 50 *permanent barriers across the channel of the river*, and then to overcome these obstructions by means of locks, which consume both money and time. While the only difficulty in the reservoir plan, appears to be the discovery of suitable sites for the artificial lakes, and this single difficulty—it can hardly be doubted—*a skilfully conducted survey will effectually remove.*

The slackwater plan, on the other hand, is beset with a number of inherent difficulties, which have been developed by long experience upon such works, on several of the well known rivers of our country.

The dams *decay or undermine*, and breaches occur in them which suspend the navigation for months; this and other difficulties are well illustrated by the Reports of the Monongahela Navigation, a work originally constructed or planned by W. Milnor Roberts, Esq., C. E.

The Fifth Annual Report, deplores *a breach* which took place "in the south end of dam No. 1, in July, 1843, which at once cut off more than one-half of the receipts of toll, prostrated the credit of the Company, and even created strong doubts of the wisdom and practicability of the undertaking;"—*as well it might.*

To close this breach required *four months time*, and the engineer in the same report dilates mournfully upon the difficulties encountered; "the works intended to repair the breach" having been "swept away by a sudden freshet;" he states further, that two dams "were considered to be in too dilapidated a condition to stand the winter and spring floods," and that the breach referred to in a dam of only 8 feet lift, "was found to be *near forty feet deep!*"

Upon the Schuylkill, the Lehigh, and Potomac navigations, *breaches* have repeatedly occurred, seriously delaying the business, and costing large sums of money in the repair.

We must therefore infer that *breaches* are a necessary incident to slackwater navigations, and that the fifty dams proposed for the Ohio, will also suffer from them.

The gates and sluices *decay and become leaky;* they sometimes give way and are sometimes knocked down by the collision of boats.*

This has occurred so often on all navigations, that special illustrations are unnecessary.

The Tenth Annual Report of the Monongahela Navigation, informs us, that "during the summer (of 1849,) the water in the river was lower than at any period since the dry season of 1838; it ceased to flow over the dams, and fell in pools No. 1 and 2 more than a foot below the wiers."

The Fifteenth Annual Report of the Monongahela Navigation acquaints us, that in 1854, "during a period of nearly three months," the navigation was "virtually suspended," and that "the water during the greater part of (the summer and fall,) not only ceased to run over the dams, but by evaporation and leakage *became almost literally dried out of the pools.*" In 1856, the navigation was suspended by drought, for about "*six months.*"

A somewhat similar experience has attended the Kentucky navigation, the Schuylkill, the Lehigh, the Potomac, the James River, and indeed, in very dry seasons, seems to be an universal attendant of slackwater navigations, even upon rivers where distinguished engineers *have calculated* that the water supply was ample.

To expect that an Ohio River slackwater would be wholly exempt from the difficulties imposed by "*droughts*" upon all others of its class, would be truly hoping against experience.

Serious, too, are the obstructions produced on all slackwaters *by ice*—the Schuylkill, Lehigh, and other similar navigations, are always stopped

* **Monongahela Navigation Reports.**

by frost about three months in each year; and the Monongahela, (a southern stream,) though usually suspended only about one month annually *by ice*, yet in 1856, *was stopped from that cause for* 94 *days!*

When we know that vast masses of ice run out into the Ohio every winter, borne upon the flowing current of the Allegheny from *the north*, can we hope that the formation of slackwater pools in the Ohio River, will fail to block up its navigation by ice for a long period in every winter season?

The Twelfth Annual Report of the Monongahela Navigation, gives a graphic account of the steamboat "*Atlantic*" bursting in the gates of lock No. 4, and the difficulties which flowed from it.

The breakage of gates by collision, even on canals operated by horse power, is a frequent occurrence, and could not fail to give abundant difficulty upon a large navigation where hundreds of steamboats run, and would sometimes be competing with each other for a passage.

Contrary to what would be expected (by many), high freshets which totally submerge the locks have "*suspended*" the trade upon the Monongahela Navigation, see Thirteenth Annual Report; the same report concisely enumerates some of the usual annual difficulties, as follows, in order to account for extraordinary drafts on the repair account, viz: "First, the removal of several loaded coal boats sunk above lock No. 1. Second, damages by high freshets in April. Third, an extraordinary repair at lock No. 2, which suspended the navigation for a month; and, Fourth, the completion of new gates in all the locks during the year."

The successive reports of the Monongahela navigation (planned by Mr. Roberts,) form very instructive reading for all who may feel inclined by specious reasoning to open a similar "Pandora's box" upon the Ohio River; they will there find, fairly and frankly stated by the officers, many of those ills that slackwaters are "heir to;" and more than enough will be found elucidated there, to induce any candid man to hesitate long before he gives his voice in favor of the repetition of such evils, on an aggregated scale upon the Ohio River; a stream which, once enchained by the system of locks and dams, that Mr. Roberts desires to impose upon it, will cease to retain any of the attributes of the "Belle Riviere," and well deserve a name drawn from the very realms of darkness itself.

Summary.

The following objections seem to be established by experience against a Slackwater Navigation on the Ohio River.

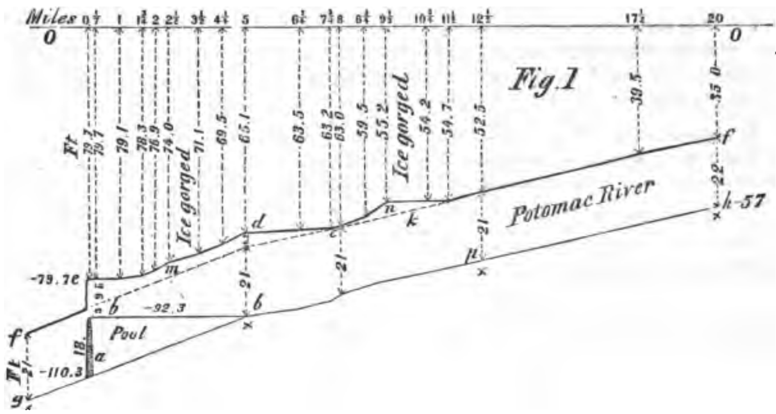
1. A seriously augmented rise of floods.
2. Excessive damages to property.
3. Prejudicial delays in lockage.
4. Breaches in the dams.
5. Breakage of lock gates.
6. Leakage of dams and locks.
7. Suspension of navigation by floods.
8. " " droughts.
9. " " ice.
10. Excessive cost of construction.
11. " " annual maintenance.
12. Necessity for reservoirs, as auxiliary.

REFERENCES TO THE FIGS. 1, 2, AND 3.

We now desire to invoke the attention of the reader to three figures, illustrative of important points in this discussion.

FIG. 1.—Profile of the celebrated *Ice Freshet*, of February 9, 1840, (so destructive on the Lehigh and Schuylkill,) as obtained from actual levels taken under the direction of the writer, upon and above the pool of dam No. 6, of the Chesapeake and Ohio Canal. The height of this freshet in the Potomac River, outside of the influence of the pool, having been from 21 to 22 feet.

Horizontal scale, ¼-inch per mile.
Vertical " " for 10 feet.
h to *p*. Fall in the river, 2¼ feet per mile.
p to *b*. " " 2 4-10ths "
b to *g* " " 3 6-10ths "
Whole descent in 20 miles from *h* to *a* =53 3-10ths feet, or at an average 2⅔ feet per mile *fall*.



a. The dam (No. 6,) a wooden crib work—the comb = 18 feet above low water, and the length of the clear water-way between the abutments being = 470 feet.

b b. Surface of pool at extreme low water, level with the comb of the dam.

f, c, d, e, f. Top level of the freshet, by accurate levels taken on the spot.

f, c, f. Top line of freshet, supposing the dam to be removed.

g h. Low water surface of the Potomac River, obtained from the levels used in the construction of the canal.

o o. Reference level or datum line.

d e. Respectively indicate the head of the pool (*d*) where in this freshet the water rose 6 2-10ths feet over the regular freshet line—and the breast of the dam (*e*), where the rise of this flood was 12 6-10ths feet over the comb, or 9 6-10ths feet above the regular freshet line of the unobstructed river.

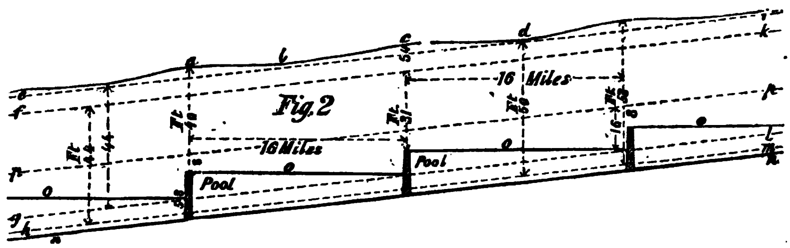
k. Point at which there was an actual ascent of the water or wave produced, of *six inches rise*, in a distance of ⅜ths of a mile down stream.

m n. Points at which the ice gorged and produced an extra rise.

NOTE.—Owing to its greater declivity, the Potomac River in an 18 or 20 feet freshet, delivers about the same quantity of water in equal times, as the Ohio River does in similar freshets.

And we may add here, that levels taken by the writer upon the Schuylkill Slackwater Navigation, verified the general features of the flood profiles of the slackwater pools on the Potomac River.

FIG. 2.—A profile illustrating the probable rise of a 44 feet freshet over 8 feet dams in the Ohio River, if converted into a lock and dam navigation, as proposed by W. Milnor Roberts, Esq., C. E.



n n. Bottom line of the available channel, average fall ½ foot per mile.

h m. Line of low water, one foot above channel bottom.

g l. Line of 6 feet deep of navigable water, or 5 feet above the low water line.

p p. *Average* surface line that a 16 feet freshet would probably take, the actual line being waved, so as to be higher at the dams and lower in the middle of the pools.

f k. Line of top water of a 44 feet freshet, supposing the river unobstructed by dams.

e i. Top water line a 44 feet freshet would take, if we suppose the bottom (or underline of flow,) elevated 5 feet, as in effect proposed by a 6 feet navigation.

a, b, c, d. Probable surface line of a 44 feet freshet, produced by the influence of the dams and pools, being from 6 to 9 feet *higher* than without them.

o, o, o, o. Surface lines of the proposed pools in low water.

Horizontal scale, ⅛th inch per mile. Vertical scale, ¼-inch for 10 feet.

From the position of one dam (*c*), to the middle of the next pool (*b*), the surface descent in a 44 feet freshet would probably be almost *doubled*, or increased from 6 inches to nearly 10 inches per mile. While from (*b*), the middle of a pool, to the place of the next dam (*a*), the surface would be found level, or nearly so, having probably only the slight slope of one inch, or one inch and a half to the mile—such a profile would be consonant with analogous facts, and with the science of hydraulics as now understood.

FIG. 3.—Sketch of the Pond of the Anthony's Creek Reservoir, Virginia: surveyed by E. Lorraine, Esq., C. E., 1851: and similar to those needed for the Ohio.

Length of pond, 9 miles. Perimeter, 46 miles; average width, ½ mile. Area of pond =2753 acres. Gathering ground or surface drained, = 65,160 acres, or nearly 102 square miles. Mean depth, 60 feet. Height of dam, 126 feet—length of dam, 395 feet. Level of outlet tunnel, 30 feet below surface of pond. *Content available in 30 feet deep*, or as low as the level of the outlet tunnel, = 2,948,106,510 cubic feet.

a. The reservoir dam, placed in the gorge of a valley.

a, b, c. The pond of the reservoir.

e f. A range of hills bounding the upper valley of Anthony's Creek.

d. Anthony's Creek.

g. Little Creek.

(3)

IMPROVEMENT OF THE OHIO RIVER.

EXPLANATORY REMARKS

ON THE

"REVIEW" OF ELLWOOD MORRIS, Esq., C. E.

BY

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Mr. Morris, for himself, having made a request that the foregoing "Review" should be printed in the same pamphlet with the "Practical Views," it was granted; the writer reserving the privilege of concluding explanations. They shall be brief, and in the same general tone as the main paper of the writer.

The Review repeats most of the statements and reasonings heretofore advanced by the friends of the Reservoir System, and offers some additional facts and remarks in its favor, while criticising the Lock and Dam System. It is rather less acrimonious towards the latter plan than were former papers.

Concerning Reservoirs.

In considering the plan of feeding the river from artificial reservoirs, the chief points, are:—

1. The annual depth of rain-fall. 2. The proportion of rain-fall that may be safely relied upon. 3. Capacity of reservoir sites relatively to the height of the dams, respectively, and the loss from evaporation from the reservoirs, and from flowing one hundred, two hundred, or more miles, between the reservoirs and Pittsburgh. 4. The cost of construction and management. 5. The practicability of establishing a sufficient number of reservoirs to produce the proposed flow of 6 feet in the Ohio River during the dry season.

1. All seem to concur in assuming about 36 inches as the probable annual rain-fall at the heads of the Ohio.

2. The proportion that may be utilized or made practically available, is claimed by Mr. Morris at nearly 50 per cent. of the downfall. Mr. Ellet, from careful measurements and calculations based on the *entire flow* of the river at Wheeling, found an average, through a series of years, of 40 per cent.; but in one year it was but 27 per cent., and for two successive years it was under 30 per cent. Had any large share of this been stored up in reservoirs, and allowed to flow only during the months of greatest evaporation, would not the quantity passing Wheeling have been reduced? Mr. Morris furnishes a table which includes several reservoirs operated by Messrs. Morris and Smith, presenting an average of 50 per cent. gathered, and giving also the writer's estimate of the quantity flowing from the West Fork Reservoir, which was 40 per cent. But in that case, the pipes connected directly with the canal supplied, and the per centage named covered the entire *leakage* of the reservoir, which was used by mills. If we take the reservoirs

surveyed by Mr. Morris, draw out the water only in droughts, and permit it to flow exposed to the sun for two hundred miles, would not a considerable proportion of the quantity originally gathered be lost? The proportion utilized in *Great Britain*, as instanced by Mr. Morris, must of necessity be larger than in this country, on account of the greater *moisture*, and the lower range of temperature, especially during the period of greatest evaporation. We all know that in our climate, during hot weather, rains occur which add no appreciable quantity to the volume of American streams or reservoirs; although measurable in the gauge. The writer expressed the opinion that from 33⅓ to 40 per cent., in different locations, was enough to allow for the quantity to be gathered; and that it was prudent to allow only about 33⅓ per cent. to be utilized as feed water for the Ohio.

3. Respecting the capacity of Reservoirs: Mr. Morris thinks it is entirely safe to assume that those proposed on the heads of the Ohio, will present a mean depth of at least 50 per cent. of the greatest *water rise* at the dams. He adduces *four* reservoirs, surveyed by himself, which show an average mean depth of but 39⅛ per cent.; the greatest being 46, and the least 27½ per cent. The writer claims, that the mean depth will on an average be nearer a *third* than *half* of the greatest water rise. The mode of calculation adopted by the engineers in arriving at the probable or approximate contents of certain reservoirs quoted, is unknown to the writer. Something depends upon this.

But, at last, this is not the *vital* point. The great object is to secure the largest *quantity of water* for a given height of dam. The future will show who is most at fault in the consideration of this part of the subject.

4. In regard to estimates of cost of the Artificial Reservoirs: the writer instanced a reservoir, previously referred to by Mr. Morris, the Conemaugh Reservoir, which is claimed by all connected with its survey and location, to be a favorable site, and it is in the very region in question. Allowing but *half* the cost of this reservoir as a gauge for an average, it showed a total of over $27,000,000 for the reservoirs. Others will judge how far this mere statement of a fact should influence their judgments in regard to the probable ultimate cost of the Reservoir System. The cost of managing, and repairing, and regulating the flow, &c., will depend very much upon the kind of system; whether numerous small reservoirs, or comparatively few large reservoirs. Mr. Morris has given an estimate, which appears to the writer to be small. It is a question which can scarcely be definitively settled in this stage of the investigation.

5. The practicability of establishing such a reservoir system as that proposed by Mr. Ellet and Mr. Morris, in the region designated, is a cardinal point. Have its advocates proved it to be reasonably practicable? Although the writer coincides with Mr. Morris in the opinion that many reservoirs are healthy, and not injurious to the country in their vicinity, that does not prove that all reservoirs, under all circumstances, will be so; or that the people immediately interested will so regard them. Something in this respect depends upon the locality, and upon the manner of drawing off the water from different reservoirs.